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POST-NATAL DEVELOPMENT OF THE HEAD

By Dr. C. B. DAVENPORT

COLD SPRING HARBOR, N. Y.

THE development of the child in the uterus has long been made the subject of careful study. Probably a scientific curiosity has led many to study a stage in human development so hidden from ordinary observation. But from birth on the development of the child is open to the observation of all. It has been taken for granted. Its changes have not, until recently, been analytically investigated. Now a beginning has been made.

The proportions of the new-born babe, with its big head and short extremities, are very obviously different from those of the adult; but again these differences, observed for millennia, have only recently been measured. As for the changes at adolescence, though noted by the mother whose son outgrows his clothes before they are worn out, their analysis has hardly begun. Precise measurement of all these changes is called for.

The earliest measurements on child growth were apparently made on the tacit assumption that there was a more or less uniform object—"the child." This child underwent changes in size and development. But since "the child" was subject to accidental fluctuation in development, the proper picture of the way this "child" grows is given not by measurement of one child, but by measuring many children, massing and averaging the measurements. Even this procedure met with the difficulty of the proper way to mass data. Commonly the age is taken as the basis of grouping; but it has been properly urged that children differ so in speed of growth that stage of development is to be considered in massing. But such a procedure meets with even greater difficulties. Gradually the conviction has dawned that "the child" as revealed by mass statistics of any sort is a bit of fiction. Reality is found only in the growth changes of individual children: Mary, John, Greta, Hans, Giovanna, Antonio, Rose and Isidore.

As a part of a program to learn how individual children grow and especially how their proportions change the measurements made upon the heads of a large number of children followed for a number of years (in extreme cases during 14 years) were assembled and generalizations drawn from them. The American Philosophical Society undertook to publish the results. Some of the findings may have a general interest and consequently are recounted here.

The human head is an extraordinary organ both on account of its relatively great size and because it encloses man's relatively large brain and carries his relatively reduced face. At the end of the first quarter of intrauterine development bony plates begin to be found around the brain, but these are not united until some months after birth.

This delay in ossification is a clear adaptation to the birth process in which, of all parts of the child, the head offers the greatest difficulties. It is the great size of the head of the new-born that offers such difficulties. At birth the head has acquired nearly 66 per cent. of its adult size; by the end of the sixth post-natal month 80 per cent.; while at birth stature is only 40 per cent. of completion. Growth of the head, especially of the brain case, is the most precocious of all parts of the body. Why is this? Of course we don't know all the circumstances that have led to the great cranial precocity of the new-born. But we can see some reasons for it; and these are mostly reasons why the brain should be so precocious. Indeed, at birth it constitutes about 12 per cent. of the weight of the body, while in the adult it constitutes only about 2 per cent. It seems probable that one reason is that the brain must be ready to perform a large part of its functions at birth. To be sure, the average baby at birth is not able to be as active as a new-born colt. In its helplessness it is more like a puppy. But its senses become quickly functional. It looks at a bright light shortly after birth. It may react to sounds within a few days after birth. The sense of taste is usually well developed. The nipple is clearly felt. The neuro-muscular system is developed enough to function in suckling and in the movement of the extremities. The latter movements, indeed, precede birth for some weeks. Within limits the neonate is a going concern.

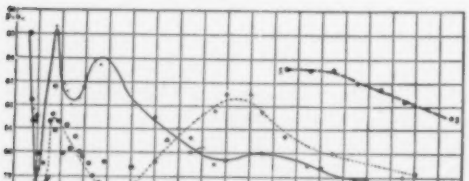


FIG. 1. CHANGE WITH AGE OF INDEX

CURVES OF MEAN CHANGE WITH AGE OF THE CEPHALIC INDEX OF NORMAL WHITE NORDIC CHILDREN. ABSCISSAE: AGE IN YEARS. "0," BIRTH. ORDINATES: THE CEPHALIC INDEX, OR THE PERCENTAGE RATIO OF HEAD WIDTH/HEAD LENGTH. SOLID LINE, BOYS; BROKEN LINE, GIRLS; DOTS, MEANS OF BABY BOYS, BIRTH TO 3½ YEARS; CIRCLES, BABY GIRLS; × AND + MALE AND FEMALE OLDER CHILDERN. S, CHANGE OF INDEX WITH AGE OF FEHMARANER (SALLER).

Another reason why the brain is so large at birth may be because it has so much to do in the course of development to be ready for more complicated mental function such as speech and all the play reactions. It is estimated that there are 13,500,000,000 neurons (or nerve cells and their fibrous prolongations) in the human cerebral cortex. Then there are additional hundreds of millions in the cerebellum. In order that these should be pretty generally available before the child begins to walk at one year the development of the brain has to begin early and proceed rapidly—more rapidly than all other, less complex, organs.

The brain case not only enlarges in the first few months after birth, but it changes shape—above all in the first few days after birth. This change of shape is well shown by changes in the cephalic index, which gives the relation of head width, above the ears, to the head length. On the average before birth the index decreases until at birth the head is relatively elongated (dolichocephalic) apparently in adjustment to the space in the uterus. During the days of adjustment to and accomplishment of the birth process the head is rendered temporarily more brachycephalic as that shape fits better the pelvic canal. For the next few months the head elongates again but subsequently tends, on the average, to become relatively wider (Fig. 1).

The brain case is, indeed, not the rigid thing that the dried skull is. During infancy and childhood it is responsive to a changing environment. If the infant lies with the back of the head sunk

in a soft pillow, or if it is fastened to a board with the occiput resting on it the head becomes flattened behind. But if it lies on the side of the head it tends to become longheaded. This has been demonstrated experimentally. However, the difference thus induced becomes mostly smoothed out in later childhood unless the pressure has been too prolonged or too rigid, as happens in flat-headed Indians and Armenians. The plasticity of the skull is shown by the fact that the distance above the ears decreases when the child begins to walk, owing to the pull of gravity, and when a boy jumps from the shed roof to the floor the form of the head may be temporarily changed by the blow received at the base of the brain case. In fact, all the way to puberty the boy's skull tends to flatten more and more at its base, doubtless due to gravity (Fig. 2).

Even in the early teens of children, after the bones of their skulls have come more or less in contact, the sides of the skull changes shape owing to the circumstance that the bone that carries the internal ear grows faster in front and below than in other radii so that the ear opening tends to move backward and upward. By this process the part of the head behind the ear ceases to grow as fast as it otherwise would (Fig. 3).

The form of the brain case is, as is generally known, very different in different races of the Old World. Thus the Negroes have a relatively long skull. The inhabitants of southern Germany and Switzerland have short skulls. These differences are apparently due to different methods of growth of the brain itself around which the case is molded. The brain case undergoes great modifications from the standard owing to defects in the growth process of the brain and bones of the skull. Thus in hydrocephalics (with water on the brain) the skull is greatly enlarged, whereas in microcephalics the brain case remains

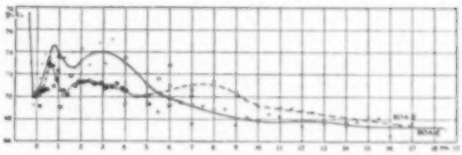


FIG. 2. HEAD HEIGHT AND LENGTH

CURVES OF MEAN CHANGE WITH AGE OF THE PERCENTAGE RATIO OF SUPRAAURICULAR HEAD HEIGHT TO MAXIMUM HEAD LENGTH, NORMAL WHITE NORDIC CHILDREN. SOLID LINE, BOYS; BROKEN LINE, GIRLS. SYMBOLS AS IN FIG. 1.

like that of an infant. The microcephalic condition has been assumed to be due to the early union of the sutures of the bones that make up the brain case, but that is certainly not the whole story, for in a certain microcephalic boy the dimensions of the brain case were still increasing during puberty, at a much faster rate than the skull dimensions of a standard child (Fig. 4). This shows clearly that even after union of the sutures the brain case can enlarge through an increase in the substance of the bones elsewhere than along their margins.

The capacity of the bones of the skull to undergo profound transformations in their very substance is well seen in the formation of the frontal sinus, the large spaces both above the root of the nose and at the level of the eyebrows. The frontal sinus varies greatly in development from nothing at all to a large, bladder-like space. Its presence becomes painfully known when the lining membrane becomes infected and drainage through the nasal sinuses is obstructed.

The sinus begins to form during early childhood in the interior of the frontal bone in the layer of spongy bone that lies between the two dense surfaces. As the pocket from the nasal cavity penetrates into this spongy tissue the two dense layers may separate widely from each other to the extent of nearly a half

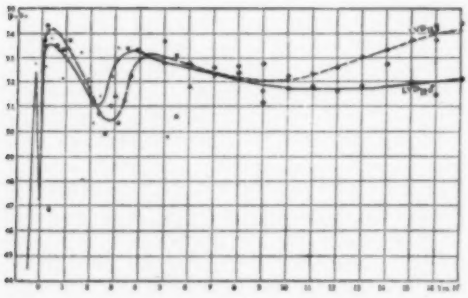


FIG. 3. EAR OPENINGS

CURVES OF MEAN CHANGE WITH AGE OF THE POST-AURICULAR TO MAXIMUM HEAD LENGTH. THIS SHOWS THAT THE PART OF THE SKULL BEHIND THE EARS BECOMES RELATIVELY LESS FROM 4 TO 10 OR 12 YEARS. EVEN LATER THE EAR OPENINGS TEND TO MOVE BACKWARD SO THAT THE POST-AURICULAR INCREASE IS LESS THAN IT WOULD OTHERWISE BE.

an inch. The whole frontal bone is remodeled during this development of the frontal sinus. The frontal sinus seems to have no important function in man. There is nothing gained by its presence, so that children who have no frontal sinus seem to function quite as normally as those who have. It is probably a rudimentary organ which was useful in the anthropoid apes with their heavy skull bones, just as the sinuses in the head of the elephant makes its weight tolerable; but in man where the skull is balanced on the end of the vertebral axis the weight of the skull becomes a relatively unimportant matter.

In the development of the head the changes in the face are very marked; indeed, one of the principal differences between the heads of the anthropoid apes and man is the great reduction of the face in the latter. In the baby at birth the face is, indeed, a very small part of the head, as it is also in newly born anthropoid apes. But whereas in the young ape the jaws develop rapidly and to great extent, in the child they remain always relatively reduced. The nose is perhaps the most prominent part of the face of the child. This develops slowly and reaches a degree of protrusion not attained in the apes.

Changes in the form of the face are largely due to the development of the jaws as the teeth are successively produced in them. Especially as the permanent dentition becomes functional and the three molars are formed the jaws begin to move forward. At the same time the great development of the maxillary sinus pushes forward still more the upper jaw to keep up with the growth of the lower jaw. Perfect occlusion of the jaws requires a harmony in the development of these two independent regions. It is perhaps not strange that we so frequently find a lack of harmony in people, with lower jaws receding or sometimes protruding, as is most strikingly seen in the bulldog.

Of the facial features one of the most striking is the pair of eyes. The human eyes have undergone a great change in position from that of very remote ances-

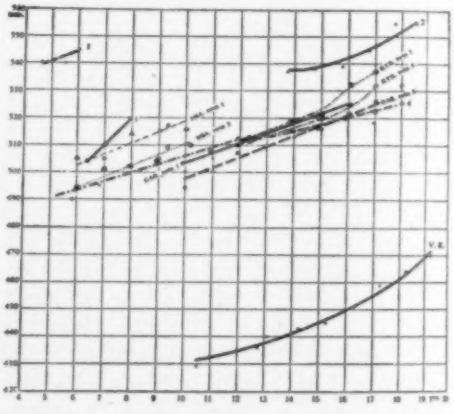


FIG. 4. GROWTH OF HEAD GIRTH

INDIVIDUAL CURVES OF GROWTH OF HEAD GIRTH OF TWINS AND SOME SPECIAL CASES. THE CURVES OF THE TWINS LIE MOSTLY CLOSE TOGETHER. CURVES 1, 2, 3 ARE OF CRETINS (LARGE HEADS). V.R. IS THE CURVE OF A MICROCEPHALIC. ITS SLOPE OF INCREASE IS AT 17–19 YEARS EVEN GREATER THAN THAT OF THE NORMAL CHILDREN.

tors. The eyes were originally paired organs as we see in fishes and even in the lower mammals, like horses. During human ontogenetic development the eyes begin as organs on the side of the head and gradually move to a position such that they look forward. This process is not completed at birth. The angle subtended by the optic nerves passing from the brain to the two orbits continues to diminish to puberty. This result is due to the interaction of two growth processes, one of which brings about the enlargement of the face as a whole and specifically in the transverse diameter and the other a tendency of the orbital angle to diminish. The first process tends to separate the eyes, the latter to bring them together. The approximation of the eyes is brought about in two ways. First, by the elevation of the root of the nose the skin is pulled away from the inner angles of the eyes. This happens in the case of European children, but in the case of the eastern Asiatics, where the root of the nose is shallow, a fold of skin persistently covers the inner angle of the eye. The second process affects the nasal and orbital bones, also partly in consequence of the reconstruction of the root of the nose. Thus the eyes, while separating as the head grows, separate less than the rest of the face and so the angle of divergence is reduced. Thus in a baby who was measured at 145 days after birth and again at 711 days the interorbital angle was reduced from 55° to 48° (Fig. 5).

Changes such as appear in the external dimensions of the skull case and the face are appearing also in the internal structure of the skull. Thus the pituitary body lies near the center of the head in the middle plane. It is largely imbedded in the sphenoid bone, one of the hardest bones in the body, and it is partly encapsuled by a bony wall. The size of this capsule (called the sella turcica) is very variable, being twice

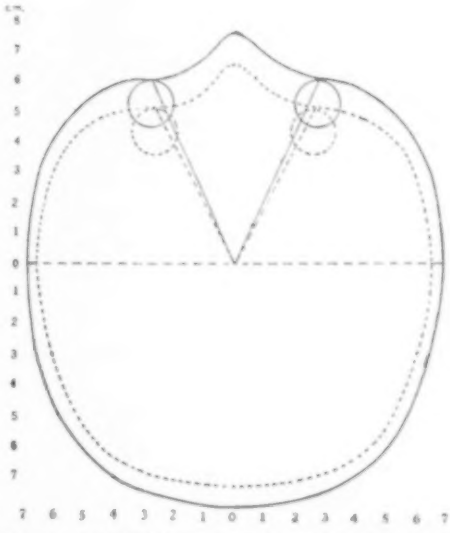


FIG. 5. HORIZONTAL SECTIONS OF HEAD

CONSTRUCTIVE OUTLINES OF HORIZONTAL SECTIONS OF HEAD OF A BABY BOY, AT THE AGE OF 145 DAYS ------, AND 711 DAYS (1 YR. 11½ MOS.) ————. THIS DISTANCE FROM INTERTRAGIAL LINE TO ORBIT IS DIRECTLY MEASURED OR COMPUTED FROM ADJACENT MEASUREMENTS. INTERPUPILLARY DISTANCE IS MEASURED (HALF THE SUM OF DISTANCES BETWEEN OUTER AND INNER ANGLES OF PALPEBRAL SLITS). THE TANGENT OF ½ INTERPUPILLARY DISTANCE DIVIDED BY TRAGION TO ORBIT IS FOUND AND DOUBLED. THE ANGLE AT 145 DAYS IS 55°.4; AT 711 DAYS 48°.3. FROM A SERIES OF MEASUREMENTS AT INTERMEDIATE AGES ASSURANCE IS GAINED THAT THE DIFFERENCE IS NOT DUE MERELY TO TECHNICAL ACCIDENTS. REDUCED TO 44 PER CENT. OF NATURAL SIZE.

as great in some children as others. This variation in size of the sella is associated with variation in size of the pituitary body. This pituitary body yields hormones of very great importance for the normal development of the child. However, the size of the pituitary body is probably not more important than the quality of the secretions which it produces so that the correlation between size of the pituitary body and the size of the body as a whole is not very large.

Now studies of the sella turcica in individual children repeated during a

number of years in the pre-, middle-, and post-adolescent periods, show that the volume of the size of the sella turcica may change regularly, generally increasing, with the growth of the body as a whole. However, in some cases the size of the sella turcica may actually diminish so that there is a readjustment of the hard bone in that the sella contracts to constitute a better fit of the shifting size of the pituitary body. It is well known, on the other hand, that the pituitary body may become enormously enlarged by the formation of a tumor in it, and under those circumstances the sella turcica becomes enlarged to meet the changes in size of the delicate pituitary body.

All these observations on the development of the head point to one conclusion, that there is first of all a set of internal directing forces in the growth of the brain and all the bones and other tissues of the head. These are the genetical factors. These developmental growth processes are, however, constantly affected by environmental conditions so that the growth may be modified by these changing conditions. Throughout development the living bones show themselves very plastic and able to reconstruct themselves as conditions demand, and the individual bone will adjust itself to the growth of adjacent bones and other tissues. The bones even respond to the pull of muscles and are largely molded by such pulls.

During the early stages of development the internal processes in the development of the head of the child show themselves to be much the same as the early processes in the head of the anthropoid apes. As later developmental processes appear the development of the skull leaves the ancestral path and strikes out in new lines, thus establishing the particular form of the human head. The path along which the human head develops even in its later stages is not a single one, however, as there are marked differences associated with sex, race, general physical and mental development and with varying functioning of endocrine glands and other growth-modifying processes. The whole study brings out clearly the fact that birth is only an incident in the development of the human being and that the post-natal changes which have been hitherto so much neglected are as real and in many cases as profound as some of the pre-natal ones.

THE DISTRIBUTION OF HUMAN GENES

By Dr. HERLUF H. STRANDSKOV
DEPARTMENT OF ZOOLOGY, UNIVERSITY OF CHICAGO

INTRODUCTION

MAN is an extremely variable species. He ranges from one who is short to one who is tall, from one who is white to one who is black, from one who is color-blind to one who has normal color vision. This list of man's variable characters could be extended almost without end.

One of the interests of the human geneticist is to find out which of man's variable characters have a hereditary basis. By this is meant to find out which of man's characters vary as a result of variations in hereditary factors. Characters may also vary as a result of variations in environmental factors, but a study of the rôle of these factors is primarily the concern of the human ecologist.

Having decided that a particular character has some hereditary basis the human geneticist proceeds to determine the exact manner in which that variable character is inherited—to decide whether it is inherited as a simple Mendelian dominant or recessive or in some more complex Mendelian way. Frequently this is not an easy task, not only because the mode of inheritance may be complex but also because man's own biological characteristics make it a difficult one. His generation span is long and his family size is small. Furthermore, society imposes certain restrictions upon the human geneticist. He is not permitted to order matings to test his hypotheses. However, despite these handicaps and restrictions, the human geneticist has determined the exact manner in which a fairly large number of variable human characters are inherited.

In recent years the human geneticist has developed a new interest. He has become interested in the distribution in populations throughout the world of the hereditary units or genes of the variable characters whose inheritance he has established. His goal is to know the distribution of all human genes in all populations—the distribution in all small local communities, in all cities, in all nations, in all races, in all primary human stocks and eventually in the population of the entire world.

Perhaps it is appropriate at this point to outline briefly what is meant by the distribution of human genes. To the person who is familiar with the laws of heredity this discussion will seem superfluous, but to the one who is not, it may serve a purpose. Every human individual develops from a fertilized egg or zygote. In that zygote are present pairs of hereditary units or genes for all of man's inherited variable characters. There are pairs of genes present because the sperm and the egg contribute each one set. Just how many pairs of genes exist in the hyman zygote is not known, but the number probably runs into the thousands. A knowledge of the exact number is not essential to our discussion. All that needs to be appreciated is that every inherited variable human character is represented by one or more pairs of genes. (Some characters may be affected by several pairs and one pair may affect several characters.) The members of a given gene pair may vary in differ-

ent individuals. For a given pair an individual may possess two similar genes or two different genes. For instance, if the genes of a given pair are represented by the symbols *A* and *a*, then an individual may possess two *A* genes (*AA*), two *a* genes (*aa*) or one of each kind (*Aa*). It will be obvious that if a population consisted of 100 individuals, 90 of whom were of the *AA* type and 10 were of the *aa* type, then the frequencies of the *A* and *a* genes in that population would be 90 per cent. and 10 per cent., respectively. Likewise, if a population consisted of 50 individuals, 2 of whom were of the *Aa* type and 48 were of the *aa* type, then the frequencies of the *A* and *a* genes in that population would be 2 per cent. and 98 per cent., respectively. In the determination of the frequencies of the genes of a variable human character it is not possible to count the genes as such, but if the mode of inheritance of the character is known, and if the frequency of the character in a population is determined, then it is possible to calculate the frequency of the gene or genes for that character in that population.

To date the distributions of only a small number of human genes have been studied and each of these in a very limited way. However, some of the studies are very interesting and informative, and it is with a few of these that I wish primarily to deal in this article. First I shall present some of the data which have been collected and then I shall attempt to relate the observed distributions to well-known evolutionary processes.

Color Vision

One variable human character whose mode of inheritance has been established and whose gene distribution has been studied to some extent is man's color vision. As every one knows, most persons can distinguish all the colors of the visible spectrum from violet to red. They are said to possess normal color vision. A few can not distinguish between the red and green colors. They are said to be red-green color-blind.

Color-blindness has probably been present in the human species from time immemorial, but its discovery dates back only to the eighteenth or possibly to the seventeenth century. At least to my knowledge no record of its occurrence appears in the literature prior to that time. In 1684 Dr. Tuberville reported to the Royal Society of London a patient who could not distinguish colors. There is some question whether this patient was red-green color-blind or had some other eye defect. A more certain case was reported in 1777 by Mr. Huddarts. In 1794 the English chemist Dalton announced his defective color vision. His announcement created so much discussion that red-green color-blindness has frequently been referred to as Daltonism. While I have no objection to a character of man being given the name of a chemist, the appellation seems inappropriate not only because it is not descriptive of the anomaly but also because Dalton was probably only partially color-blind.

That red-green color-blindness has a hereditary basis was realized soon after its discovery. Its exact mode of inheritance, however, was not established before 1910 or 1911. At that time it became appreciated that red-green color-blindness is inherited as a sex-linked recessive character. By this is meant that the gene for color-blindness (*cb*) is carried in the X-chromosome and that this gene does not express itself except in the *absence* of the gene for normal color vision (*Cb*).

As early as the middle of the nineteenth century attempts were made to estimate the frequency of red-green color-blindness in various populations throughout Europe and the United States. Most of these estimates were inaccurate, due either to smallness of

number tested or to unreliable ways of determining the character. Oddly enough, one estimate was made by a poet and found its way into poetry. In 1878 the American poet Oliver Wendell Holmes wrote inquiringly as follows:

> Why should we look one common faith to find,
> Where one in every score is blind?
> If here on earth they know not red from green,
> Will they see better in things unseen?

Holmes's estimate of one color-blind in every twenty is nearly correct. It is especially so if we have in mind a typical American population. In other populations, as I shall point out later, the frequency may be considerably different.

An interesting feature of red-green color-blindness is its greater rarity among women than among men. For a long time it was believed that this difference was due merely to a greater familiarity with colors on the part of women. Colored yarns were used for testing purposes and it was thought that some color-blind women recognized red and green colors even though they did not see them as such. We know now that this explanation is not the correct one, and that the real explanation lies in the manner in which color-blindness is inherited. According to theory, the frequency of a sex-linked recessive character, among the females of a population in which mating is at random, should be equal to the square of the frequency of the character among the males. Thus, if 10 per cent. (1/10) of the males of a population show a sex-linked recessive character, then only 1 per cent. (1/100) of the females should show it.

In Table I are given the percentage frequencies of color-blindness among the males and females of a number of populations from various regions of the world. This list does not include all the studies which have been made, but it does include most of the recent ones in which Ishihara's color charts have been used for diagnostic purposes. It would be desirable to have this list extended. Particularly welcome would be data from Africa, Italy, India, Japan, Russia and England, and also from additional racially distinct populations in the Americas.

Table I also gives the percentage frequencies of the color-blind gene (*cb*) and of the normal color vision gene (*Cb*) in the populations listed. These percentage frequencies are not given separately, but they can be read directly from the frequencies of the character among the males. The frequency of a sex-linked recessive gene, in a population mating at random, is the same as the frequency of the character among the males of that population. Thus, for instance, if 10 per cent. of the males of a population show a sex-linked recessive character, then the frequency of the sex-linked recessive gene for that character is 10 per cent. It follows, of course, that the frequency of the sex-linked dominant gene for the opposing character is 90 per cent.

Let us examine the percentage frequencies given in Table I. It will be seen that the frequency of color-blindness among the males of Norwegian and German populations is about 8 per cent. This means that there are in these populations about 8 color-blind genes (*cb*) for every 98 normal color vision genes (*Cb*). Other studies indicate that these frequencies hold for most north European countries. As shown in Table I they also hold for U. S. Caucasoids. A somewhat lower incidence is recorded for American Jews and American immigrant Spaniards when they are considered independent of other American Caucasoids. Among U. S. Negroes the color-blind gene (*cb*) is only about half as common as it is among U. S. Caucasoids; consequently, there are proportionately only about half as many color-blind Negroes in the United States as there are Whites. Among Chinese the

TABLE I

FREQUENCY OF COLOR-BLINDNESS AND OF THE COLOR-BLIND GENE (cb) IN VARIOUS POPULATIONS

Population	Investigator	Males		Females	
		Number tested	Per cent. color-blind	Number tested	Per cent. color-blind
Norwegians (Oslo)	W	9,049	*8.0	9,072	.4
Germans	P	2,000	8.0	3,000	.4
Caucasoids, U. S. (Unselected)	G	795	8.4	232	1.3
Caucasoids, U. S. (Unselected)	M	1,286	8.2	....	..
Caucasoids, U. S. (Jews)	G	200	4.0	175	0.0
Caucasoids, U. S. (Spaniards)	G	346	3.8	390	0.8
Mexicans (Old Mexico)	G	571	2.3	494	0.6
Mexicans (Immigrants, U. S.)	G	523	2.5	469	0.9
Negroes, U. S.	Cl	325	3.7	....	..
Negroes (South U. S.)	G	538	3.9	496	0.8
Negroes (North U. S.)	G	254	2.8	165	0.0
Chinese (Chengtu)	K–B	1,115	6.3	....	..
Chinese (Peiping)	CH	1,164	6.9	1,132	1.7
Indians, U. S.	Cl	624	1.9	202	0.0
Indians (various tribes)	G	562	2.5	337	0.0
Indians (Navajo)	G	535	1.1	456	0.7
Indians (mixed blood)	G	480	5.2	523	0.8

* The percentage frequency of color-blindness among males is also the percentage frequency of the color-blind gene *cb* in the population.
Ch = Chang, Cl = Clement, G = Garth, K–B = Kilborn and Beh, M = Miles, P = von Planta, and W = Waaler.

color-blind gene has a fairly high incidence. Its frequency is about midway between those of U. S. Negroids and U. S. Caucasoids. Among U. S. Indians its incidence is the lowest found in any group so far.

Probable explanations for the distributions of the color vision genes and those of other characters will be reviewed later.

ABILITY TO TASTE

Another human character whose exact mode of inheritance has been established and whose gene distributions have been studied to some extent is the inability to taste the chemical phenyl thiocarbamide. (We shall refer to this chemical as P. T. C.) About ten years ago a chemist was preparing some P. T. C. in one of America's chemical laboratories. While doing so some of the chemical escaped into the air and a co-worker complained bitterly about its taste. This complaint surprised the first chemist, because he was not aware of any taste. In fact, he could not taste the substance, even though a considerable quantity of its crystals was placed upon his tongue. To decide who was the odd or peculiar individual the two chemists called in several other men to act as jurors. To the astonishment of all present some could taste the chemical while others could not. To all those who could taste it, the taste was bitter. The rest could taste nothing.

News of this striking difference among human individuals reached human geneticists. It aroused their interest, and soon thousands of people were tested for their ability to taste P. T. C. In a short time it was discovered that about 70 per cent. of American people are P. T. C. "tasters" and 30 per cent. are "non-tasters." These studies also revealed that the inability to taste P. T. C. has a familial incidence and that it is inherited as an autosomal recessive. Matings between "non-taster" and "non-taster" give only children who are "non-tasters," whereas matings between "tasters" or between "non-taster" and "taster" may give some children who are "tasters" and some who are not.

In Table II are given the percentage frequencies of "taster" and "non-taster" groups in populations from various regions of the world. The frequencies for the "taste" gene (*T*) and for the "non-taste" gene (*t*) are also given. These gene frequencies have been calcu-

lated directly from the "non-taster" group. In a population in which mating is at random the frequency of an autosomal recessive character should represent the square of the frequency of the autosomal recessive gene. Thus, if the frequency of the autosomal recessive character is known, it is possible to calculate the frequency of the autosomal recessive gene by extracting the square root of the frequency of the recessive character. For example, if an autosomal recessive character has a frequency of 25 per cent. (1/4) in a population mating at random, then the frequency of the recessive gene in that population is 50 per cent. (1/2).

It will be seen that the "non-taste" gene (t) is about equally common in Caucasoid and Negroid populations. At least there is no striking difference between these two groups. Among Mongoloids it is somewhat rarer. Of interest is the uniformity of the t gene frequencies among all Mongoloids. Even the full-blooded American Indians have about the same "non-taste" gene frequency as do Japanese and Chinese populations.

Pitch of Voice

Here I should like to call attention to a variable human character which has not been studied extensively, but whose inheritance and whose gene distributions should prove of interest to many. Some years ago it was discovered that the pitch of the human voice is influenced by one major pair of autosomal genes. Interestingly enough, these genes express themselves differently in the two sexes. A man who is the possessor of the two similar genes ($V^{ba}V^{ba}$) sings bass, while a woman who is the possessor of the same two genes sings soprano. In the table which follows are given the voices resulting from the various gene combinations:

	$V^{ba}V^{ba}$	$V^{ba}V^{ta}$	$V^{ta}V^{ta}$
Male	Bass	Baritone	Tenor
Female	Soprano	Mezzosoprano	Alto

From the table above it will be obvious that a marriage between a basso and a soprano can give only children who sing bass or soprano; and a marriage between a tenor and an alto can give only children who sing tenor or alto. Only a baritone and a mezzosoprano can hope to produce a quartet.

Although the distributions of the bass-soprano gene (V^{ba}) and of the tenor-alto gene (V^{ta}) have not been studied extensively, there is some evidence that the former has a higher incidence in northern Europe than it does in Italy and other Mediterranean countries, and, con-

TABLE II

Frequency of the Phenyl Thiocarbamide "Taster" and "Non-taster" Groups, and of the T and t Genes in Various Populations

Population	Investigator	Number tested	Group percentages		Gene percentages	
			Taster	Non-taster	T	t
Caucasoid, U. S.	S	3,643	70	30	45	55
Caucasoid, U. S.	P	439	69	31	44	56
Southern Jew (Palestine)	Y	175	72	28	47	53
Northern Jew (Palestine)	Y	245	68	32	44	56
Semenites (Palestine)	Y	59	68	32	43	57
Arabs (Syria)	H–P	400	63	37	40	60
Egyptians	H–M	208	76	24	51	49
Negroes, U. S. (Alabama)	H–C	533	77	23	51	49
Japanese	R	8,824	93	7	73	27
Chinese	C–C	167	94	6	75	25
Formosans (Aborigines)	R	1,756	95	5	77	23
Formosans (Chinese origin)	R	5,933	89	11	68	32
Indians F. B. (U. S.)	L–A	183	94	6	75	25
Indians M. B. (U. S.)	L–A	110	87	13	64	36

C–C = Chen and Chain, H–C = Howard and Campbell, H–M = Hickman and Marcos, H–P = Hudson and Peter, L–A = Levine and Anderson, P = Parr, R = Rikimaru, S = Snyder, Y = Yunovitch.

versely, that the latter has a higher incidence in southern Europe. As yet no studies of the distribution of V^{bs} and V^{ta} genes in the United States have been made.

The A–B Blood Groups

Of all human characters which have been proved to have a genetic basis, the A–B human blood groups have been studied the most, not only with respect to their importance in blood transfusions, but also with respect to the distributions of the genes responsible for them. These studies have literally run into the hundreds. Many of them have not been extensive, but when they have been carefully done, they have contributed something to our knowledge of human gene distributions.

Human bloods, as every one knows from his acquaintance with blood transfusions, fall into four major groups. The names given to these four groups are: AB, A, B and O. These names are given on the basis of (1) the presence or absence of one or both of two agglutinable substances (isoagglutinogens), A and B, which are found in the red blood cells, and (2) the presence or absence of one or both of two agglutinating substances (isoagglutinins), a and b, which are found in the blood serum. The relationships of these substances to the groups are shown in the table which follows:

Blood group	Isoagglutinogen	Isoagglutinin
AB	A and B	None
A	A	b
B	B	a
O	None	a and b

It will be noticed that if an isoagglutinogen is present in the red blood cells of an individual, then the corresponding isoagglutinin is absent in the serum of that individual. In blood transfusions the important consideration is not to introduce isoagglutinogens in the blood of the donor which will be agglutinated by isoagglutinins in the blood of the recipient or host.

As was implied in an earlier statement, the A–B blood groups have been shown to have a hereditary basis. Furthermore, they have been shown to be inherited in accordance with a theory of triple allelomorphs. By this is meant that a given locus on a chromosome is represented by three different genes which can combine in all different ways in groups of two. The three genes responsible for the four human blood groups have been called the I^A, the I^B and

TABLE III

Frequency of Blood Groups AB, A, B and O and of the Blood Group Genes, I^A, I^B and i in Various Populations

Population	Investigator	Number investigated	Group percentages				Gene percentages		
			AB	A	B	O	I^A	I^B	i
Caucasoid, U. S.	Sn	20,000	4	41	10	45	26	7	67
Caucasoid, U. S.	Sa	3,000	4	42	9	45	27	7	66
Germans (Heidelberg)	D	500	5	43	12	40	28	8	64
Germans in Hungary	V–W	476	3	43	13	41	27	8	65
Hungarians	V–W	1,500	12	38	19	31	29	17	54
Gypsies (Hungary)	V–W	385	6	21	39	34	14	26	60
Hindus (N. India)	H–H	1,000	9	19	41	31	15	29	56
Negroes (West Africa)	L–H	325	3	22	23	52	13	14	72
Negroes (U. S.)	Sn	500	5	28	20	47	18	13	69
Japanese (Ou district)	F	24,672	9	37	23	31	26	18	56
Chinese (Peiping)	L–W	1,000	10	25	35	30	20	26	54
Chinese (Hunan)	L–C	1,500	10	38	21	31	28	17	55
Indians F. B. (Peru)	L	200	00	00	00	100	00	00	100
Indians F. B. (U. S.)	Sn	453	00	8	1	91	4	1	95
Indians F. B. (Blackfeet)	M–L	394	1	77	00	22	54	1	45
Indians M. B. (Blackfeet)	M	235	2	51	2	45	31	2	67

D = von Dungern, F = Furuhata, H–H = L. and H. Hirzfeld, L = Larreta, L–C = Li Chi Pan, L–H = Lewis and Henderson, L–W = Liu-Wang, M = Matson, M–L = Matson, Levine and Schrader, Sa = Sanford, Sn = Snyder, V–W = Verzar and Weszecsky.

TABLE IV

TABLE SHOWING THE FREQUENCY OF THE BLOOD GROUPS MM, MN AND NN AND OF THE BLOOD GROUP GENES A^m AND A^n IN VARIOUS POPULATIONS THROUGHOUT THE WORLD

Population	Investigator	Number investigated	Group percentages			Gene percentages	
			MM	MN	NN	A^m	A^n
Caucasoids, U. S.	L–L	532	26	54	20	53	47
English	T–P	422	29	47	24	52	48
Germans	Bk	2,000	29	49	22	54	46
Russians (Leningrad)	Bv	763	32	47	21	55	45
Hindus	C	300	43	47	10	66	34
Negroes, U. S.	L–L	181	28	47	25	51	49
Chinese	R	1,029	33	49	18	58	42
Japanese	H	1,000	29	51	20	55	45
Ainu	K	504	18	50	32	43	57
Eskimos (East Greenland)	F–H	569	83	16	1	91	9
Indians, U. S.	L–L	205	60	35	5	78	22
Indians, F. B. (Pueblo)	A–L	140	59	33	8	76	24
Indians, F. B. (Blackfeet)	M–S	95	55	40	5	75	25
Indians, M. B. (Blackfeet)	M–S	272	18	56	26	46	54

A–L = Allen-Larson, Bk = Blaurock, Bv = Blinov, C = Combined results, F–H = Fabricius-Hanson, H = Haschimoto, K = Kubo, L–L = Landsteiner and Levine, M–S = Matson, Levine and Schrader, R = Ride, T–P = Taylor and Prior.

the *i* genes. The following table shows the gene combination (or combinations) responsible for each group:

Blood group	Gene combination
AB	I^AI^B
A	I^AI^A or I^Ai
B	I^BI^B or I^Bi
O	ii

As indicated in an earlier paragraph, hundreds of studies on the frequency of the human blood groups have been made. It would be neither possible nor appropriate to introduce all of them here. A few have been chosen for representative purposes. These are given in Table III. In Table III are also given the frequencies of the three blood group genes. These gene frequencies have been calculated from the observed group frequencies. According to theory an estimate of the frequency of the I^A gene may be obtained by extracting the square root of the sum of the frequencies of groups B and O, and subtracting this result from 1. Likewise, an estimate of the frequency of the I^B gene may be obtained by extracting the square root of the sum of the frequencies of groups A and O and subtracting this result from 1. And finally, an estimate of the frequency of the *i* gene may be obtained by subtracting from 1 the sum of the calculated frequencies of the I^A and the I^B genes.

Among northern Europeans and U. S. Caucasoids the *i* gene has a frequency of about 66 per cent. As a result nearly half of the people of these populations belong to group O. The I^B gene on the other hand is comparatively rare in these populations and consequently the B group and also the AB group are rare. In southern and southeastern Europe the I^B gene is more common and the I^A gene is less common than the respective genes are in northern Europe. Among Negroids the *i* gene is apparently slightly more common than it is among Caucasoids. The I^A gene frequency on the other hand is relatively low. Among Mongoloids the A–B blood group genes are extremely variable in frequency. Among Chinese and Japanese the I^A and I^B gene frequencies are relatively high. The I^B gene is particularly common in comparison with its frequency among Caucasoids of northern Europe. However, it is not more common among these populations than it is among the Caucasoids of India. Among some Indian tribes of the United States and of Peru the I^A and I^B genes are nearly absent. In fact, it is believed by some that they are completely absent among full-blooded Indians of these tribes. Among the Blackfeet Indians of the U. S. Northwest, on the other hand, the I^A gene has

the highest frequency that has been discovered for any human population, be it Mongoloid, Negroid or Caucasoid.

The M–N Blood Groups

In addition to the four A–B blood groups, and entirely independent of them, human bloods fall into three other classes. These are the MM, the MN and the NN groups. The M–N groups differ from the A–B series in that their agglutinating substances (agglutinins) are never normally present in human blood. They must be induced in the tissues of other animals.

The M–N blood groups are also inherited, but in a manner somewhat different from the A–B series. The three M–N groups are dependent upon the presence or absence of one or the other of a pair of genes called the A^m and the A^n genes. The table which follows shows the gene combinations responsible for the three groups:

Blood group	Gene combination
MM	A^mA^m
MN	A^mA^n
NN	A^nA^n

Neither the A^m nor the A^n gene is dominant over the other. Matings between individuals of group MM and of group NN produce children all of whom belong to group MN; and matings within the MN group produce children ¼ of whom are expected to belong to group MM, ½ to group MN, and ¼ to group NN.

In Table IV are given the M–N group frequencies and the A^m and A^n gene frequencies for a number of populations. The A^m and A^n gene frequencies have been calculated directly from the group frequencies. Since neither the A^m nor the A^n gene is dominant over the other it is possible to obtain the gene frequency of a population from the group frequencies. In any population the A^m gene frequency equals the MM group frequency plus ½ the MN group frequency; and the A^n gene frequency equals the NN group frequency plus ½ the MN group frequency.

It will be evident from a study of Table IV that the A^m and the A^n gene frequencies are nearly the same for a majority of all Caucasoid, Negroid and Mongoloid populations. The peoples showing the greatest deviations from the average are the Ainu and the Eskimos of Greenland. The Ainu have a relatively low A^m and a relatively high A^n frequency, while the Greenland Eskimos have a very high A^m and a very low A^n frequency. The American Indians resemble the Eskimos of Greenland somewhat in having a relatively high A^m and a relatively low A^n frequency. However, the deviation from the average is not so great for the Indians as it is for the Eskimos. Since the Blackfeet Indians have been shown to differ so strikingly from other Indian tribes in their I^A and i gene frequencies, it is an interesting fact that they are very similar to other Indian tribes in their A^m and A^n gene frequencies.

Shape of Red Blood Cells

The distributions of the genes for several other inherited human characters could be reviewed, but only those of one more will be mentioned, namely, those for the shape of human red blood cells. The red blood cells of certain human individuals become crescentic or sickle-shaped when their blood is exposed outside of the body to certain special conditions. Some individuals whose blood shows these peculiar cells are anemic; consequently, the character was originally called sickle-cell anemia. Anemia, however, does not always accompany the character; therefore, it seems more appropriate to refer to the character as sickle-shaped erythrocytes. Sickle-shaped erythrocytes is of interest to human geneticists because it has been proved to have a hereditary basis, and

also because it has been found only among Negroes.

According to the few genetic studies which have been made, sickle-shaped erythrocytes is inherited as an autosomal dominant. The dominant gene for sickle-shaped erythrocytes has been called the *Si* gene, and the recessive gene for the opposing normal red blood cells the *si* gene. Only a few estimates of the frequency of sickle-shaped erythrocytes have been attempted, but all these indicate that about 7 per cent. of all American Negroes possess this character. If this estimate is correct, then the *Si* and the *si* genes have frequencies in the American Negro population of about 4 per cent. and 96 per cent., respectively. As far as I am aware, no studies have been made of the incidence of sickle-shaped erythrocytes in Africa. Such studies woud be interesting and welcome.

Probable Explanations

Having reviewed in a somewhat summary fashion the observed distributions of the genes of a few variable human characters, I shall attempt to account briefly for these distributions in terms of well-known evolutionary factors. No final answers can be given, but a few probable explanations can be presented.

At the basis of all genetic variability and consequently of all gene distributions is the factor of genetic change. Without this factor operating there would be no genes to be distributed. Without it there would be no human species, not even lower forms as we know them—probably no life at all.

Genetic changes are fundamentally of two kinds: Those which represent visible changes in the larger units of the cell, called the chromosomes, and those which represent changes in the ultimate hereditary units or genes. The former are known as chromosome mutations and the latter as gene mutations. We shall be concerned primarily with the latter, not because the former have played no rôle in the evolution of man (they probably have played an exceedingly important rôle), but because a discussion of them appears to lie outside the scope of the present article. We shall be concerned only with the distribution of human genes and not with the detailed story of human evolution.

New gene mutations are fairly common. At least they are so among lower forms. Any one working with the small fruit-fly (*Drosophila*) for any length of time will, if he is an acute observer, sooner or later discover a new mutation. Hundreds of them have been reported and established for this form. Even within the human species several new mutations have been observed. A few years ago a type of permanent hair cut appeared as a new character in a Norwegian family. The hair grows out a few inches and then breaks off. Because the hair is also extremely curly the new mutation has been called "Woolly Hair." This character is inherited as a Mendelian dominant. A number of other specific illustrations of human mutations could be cited, but suffice it to say that mutations do occur in man and not infrequently so. One estimate places the rate of mutation of a particular human gene at one mutation for every 50,000 individuals per generation.

In accounting for the human gene distributions which have been observed I shall ask three questions and then attempt to answer each of them. The three questions are: (1) How can the differferences, in the extent to which various human gene mutations are distributed, be explained? (2) How can the high or low frequencies of the observed human gene mutations be accounted for? (3) How can the differences in the frequencies of the same gene in different populations be explained?

The time at which a given gene mutation occurs in the evolutionary history of

a species is an important factor in its subsequent distribution. If it occurs before a species has become separated into numeorus distinct populations it has a better chance of becoming universally distributed than if it occurs later, for it can be carried directly by all populations as they radiate out from the ancestral stock. Regarding the human gene mutations whose distributions have been reviewed, there is reason to believe that most of them appeared early in the evolution of man. The only exception is probably the *Si* gene for sickle-shaped erythrocytes. Since this gene is found only among Negroes, it seems probable that it represents a mutation of relatively recent origin.

The best available evidence that some of the observed human gene mutations are of ancient origin is given by the A–B blood group genes. According to several investigators the Anthropoid apes possess A and B isoagglutinogens which are serologically identical with those found in man. Even all the four blood groups found in man have been discovered for the Anthropoid apes. This fact can only mean that these first cousins of man possess blood group genes identical with or at least very similar to those present in man; and it suggests strongly that the mutation or mutations which are responsible for the blood group genes in both lines occurred early in the common ancestral stock. There is even a suggestion that these mutations may have occurred earlier in the evolutionary history of mammals, because there is some evidence that A–B blood groups exist below the primate branch.

A gene mutation need not necessarily occur in the ancestral stock of a species in order for it to become universally distributed. It is possible for it to be distributed as a result of migrations and intermarriages. While this is a possible explanation for the common occurrence of a number of human genes, it is not a very probable one for the universal distribution of most of the mutations which have been reviewed. Intermarriages between different primary human stocks have not taken place to this extent in the remote or even in the recent past. However, it seems certain that this factor will play a greater and greater rôle as time passes. With modern methods of communication and travel this can not be prevented. For instance, it seems certain that the sickle-shaped erythrocyte gene (*Si*) will eventually filter into the Caucasoid and Mongoloid stocks.

Another way in which a given kind of gene mutation may become universally distributed, without appearing as a result of a mutation in the common ancestral stock or as a result of intermarriages between populations, is for the same mutation to appear in all populations. There is ample evidence from studies with lower forms that this may occur. Duplicate gene mutations have even been reported for man. For instance, the gene for normal blood clotting (*H*) has been reported to mutate in different populations to the gene for haemophilia (*h*). Some investigators are of the opinion that the occurrence of duplicate gene mutation is the most probable explanation for the universal distribution of the blood group genes among human populations and also for their common occurrence among Anthropoid apes and man. While I admit this possibility, I am inclined to believe that the ancestral mutation hypothesis is the more probable. I recognize, however, that some of the blood group genes which are found in both Anthropoid ape and human populations may represent recent mutations.

The second question which is to be answered concerns the high and low frequencies of the different observed human mutations. How are the high frequencies of many of the observed gene mutations to be accounted for? Many people

are of the opinion that if a new character appears in a population and that if it has a hereditary basis, then it will automatically persist and increase in frequency. This is an unwarranted assumption. Heredity in and of itself does not insure persistence of a new mutation nor does it by itself bring about an increase in frequency of that mutation. Such increases, if they do occur, are due to other factors.

Among the more important factors which may lead to a persistence and an increase in the frequency of a new mutation is Natural Selection. Gene mutations are random or nearly random in nature. They apparently bear no specific relationship with the environment in which they occur. Since they are random or at least nearly so it is not surprising to find that most of them have a negative survival value for the individual or the species in which they occur. By negative survival value is meant that they tend to produce individuals who will not survive as readily or leave as many offspring as the individuals who show the character of the original gene. Obviously such mutations which have a negative survival value will tend to be eliminated from a population.

A fairly large number of the mutations which occur are said to be indifferent. By this is meant that they are neither selected for nor against. Such mutations should remain constant in frequency so far as natural selection is concerned but may disappear or increase in frequency for reasons which will be presented later. A few mutations have a positive survival value. By this is meant that the individuals who show the mutations will tend to survive to a greater extent than the individuals who show the character of the original gene. Naturally such gene mutations will tend to increase in frequency in a population. It does not follow, however, that all of them will survive.

Of the human gene mutations whose distributions have been reviewed, only a few seem to have a higher or lower survival value than the genes from which they mutated. These are the color-blind gene (*cb*) and the sickle-shaped erythrocyte gene (*Si*). It seems probable that in a primitive society the color-blind gene (*cb*) may have a slightly lower survival value than the gene for normal color vision (*Cb*). This may account for its relatively low incidence among full-blooded Indians and among Negroes. Their civilizations in which selection might have operated against the *cb* gene are more recent than those of the other peoples whose gene frequencies have been studied. It might seem to some persons that in a modern society which employs red and green "stop and go" signals, selection would also operate against the *cb* gene. The opposite is probably true. Color-blind men are not allowed to drive locomotives and other vehicles of traffic. Furthermore, it has been a custom in the past to exempt color-blind men from active participation in wars and other hazardous activities. Such exemption would naturally tend to increase the frequency of the *cb* gene. Recent discoveries may alter this trend. It has been reported recently that color-blind men can spot certain bombing objectives from the air more readily than men with normal color vision. If this should turn out to be true, then there may be a special demand for color-blind men in a very hazardous occupation and the frequency of the *cb* gene should then decrease.

The *Si* gene appears to have a negative survival value because anemia is frequently associated with the sickle-shaped erythrocyte condition. I must admit, however, that I do not know to what extent this form of anemia leads to death or to decreased reproductive capacity, but it seems probable that it does to some extent.

There is one more of the introduced variable human characters whose genes may have a differential survival value. This is the pitch of the human voice. It seems probable that either the bass-soprano gene (V^{bs}) or the tenor-alto gene (V^{ta}) may have a lower survival value than the other, but in view of a possible storm of protest, I shall not voice an opinion against the one or the other.

A number of attempts have been made to establish a differential survival value for the blood group genes. But to date no positive or negative survival value has been found for any one of them. Likewise no differential survival value has been discovered for the ability or inability to taste the chemical phenyl thiocarbamide.

If selection has not been responsible for the high incidence of most of the gene mutations whose distributions have been reviewed, what factor has? Perhaps the most important one has been recurrent mutations. We have already pointed out that the same mutation may occur in different populations. Naturally if this is true it may also recur in a given population. If a certain mutation recurs very often in a given population it will increase in frequency in that population in the absence of selection. It may even increase in the presence of a low selection pressure. As far as I am aware there is not much direct evidence that the blood group genes or the taste genes are mutating, but this is not surprising in view of the fact that these characters are not detected unless special tests are used. Other mutations like haemophilia are known to recur fairly frequently. In fact, it was the gene for normal clotting (H) which was estimated to mutate to the haemophilia gene (h) as often as once in every 50,000 individuals per generation.

Although recurrent mutations as a factor have been given credit for many of the observed high frequencies of human gene mutations, it must be pointed out that a gene may have an effect which has a positive survival value even though the character associated with it does not. Many genes have multiple effects and their most important effects are frequently not discovered. Thus natural selection may frequently be playing an unsuspected rôle. Furthermore, it should be emphasized that the positive survival value of a gene need not be very great for a marked increase in gene frequency if a long time is allowed for selection to operate.

The third question which is to be answered concerns differences in the frequencies of a given gene in different populations. For instance, what explanation can be offered for the complete absence of the I^A gene among Indians of Peru and the high incidence of the same gene among the Blackfeet Indians of the U. S. Northwest? Perhaps the most probable explanation for a number of these differences is the matter of chance. If an original large population has a fairly high incidence of a given mutation and if from that population a number of small populations migrate to distant regions, then there is the possibility, merely as a result of chance, that one group will carry away a high frequency of the mutation and another a low one. It seems probable that this is at least a partial explanation for the blood group frequency differences among Indians. It probably also is the best explanation for the high A^m and the low A^n gene frequencies of the Eskimos of eastern Greenland.

If the group which migrates from the original population is large or representative of the population as a whole, then the gene frequencies in the new population should resemble closely those of the old or original one. Examples of this are common. The similarity of the blood group gene frequencies of the U. S. Negroes and those of West Africa is a case

in point. Two other interesting illustrations were brought to light some years ago. In 1922 two investigators tested the bloods of a colony of Germans who were living in Hungary but who were not intermarrying to any extent with the surrounding Hungarians. When their blood group frequencies were calculated they were found to resemble more closely the blood group frequencies of the Germans of Heidelberg, from where their ancestors had migrated 200 years earlier, than the frequencies of the surrounding Hungarians. The same two investigators tested the bloods of a colony of gypsies, also living in Hungary without intermarrying with the Hungarians. When their blood group frequencies were calculated they were found to resemble more closely those of the Hindus of North India than those of the Hungarians. The interesting part of this story is that when the history of these gypsies was checked it was found that a philologist had decided, on the basis of their language, that the ancestors of this particular gypsy colony had migrated from North India 500 or more years earlier.

Another possible explanation for gene frequency differences in different populations is for the same gene to have different mutation rates in different populations. Such mutation rate differences have been reported for genes among lower forms, but there is no direct evidence of such mutation rate differences in man. It is true that one geneticist has used this explanation to account for the high I^A gene frequency among the Blackfeet Indians and the low frequency of the same gene among other U. S. Indian tribes. While I must admit this explanation is a possible one, it does not appear to me to be the most probable one.

Of course, if a gene has a positive or a negative survival value and if two populations exist under different environmental conditions, then selection alone may be responsible for the frequency differences. As was pointed out in an earlier paragraph, this seems a probable explanation for some of the observed frequency differences of the color-blind gene.

Many more factors and combinations of factors could be brought forth as possible and even as probable explanations for some of the observed gene distributions, but with only a limited amount of data collected such detailed discussion seems too speculative at the present time.

The Value of Human Gene Distribution Studies

Undoubtedly the greatest value of human distribution studies will be to a clarification of human racial interrelationships and to an understanding of human evolution in general. However, human distribution studies may also have some practical value. It would seem that they may be of some value in the formulation of medical and other social programs. There appears to be some value in knowing the percentage of children who will be born each year with haemophilia, with sickle-shaped erythrocytes, with color-blindness or with any other of the definitely inherited human anomalies. All in all, the study of human gene distributions promises to be one of the most fruitful avenues of research which has been opened up in the field of human biology within recent years. It is a tremendous project which requires and deserves the joint cooperation of the human geneticist, the physician, the anthropologist, the human ecologist and any other person who is interested in the story and the welfare of the most interesting of all animals, MAN.

THE NORMAL BURNING OF GASEOUS EXPLOSIVE MIXTURES

I. Explosions at Constant Pressure and at Constant Volume

By Dr. ERNEST F. FIOCK
PHYSICIST, NATIONAL BUREAU OF STANDARDS

Introduction

In a recent reference book called "Combustion Flames and Explosions of Gases" Lewis and von Elbe[1] make the following logical subdivisions in the field of combustion research: (1) the kinetics of reactions in the gas phase, usually involving studies of reactions which take place simultaneously throughout all the gas mixture, (2) the passage of flame progressively through the gas mixture, with consequent existence of a surface or region of demarcation between the burned and unburned gases, and (3) the state of the burned gas.

Since the scope of the present report must be limited, and since the experience of the author has been in the field involving progressive flames, the discussion will be confined, for the most part, to the second of the three phases mentioned above. Further limitation is made by including only explosions involving normal burning, that is, burning in the absence of detonation, except in the case of combustion in the engine cylinder where detonation or knock has been the principal subject of investigation.

It may not be amiss to begin with a brief historical background, recalling the principal elements of the foundation upon which recent studies of the combustion process are based. The following section is a digest of a detailed presentation made by Bone and Townend.[2]

[1] B. Lewis and G. von Elbe, "Combustion Flames and Explosions of Gases," London: Cambridge University Press, 1938.

[2] W. A. Bone and D. T. A. Townend, "Flame and Combustion in Gases," London: Longmans, Green and Company, 1927.

Historical

Judging by modern standards, it appears that the earliest truly scientific studies of flame and combustion were made by Robert Boyle and his pupils about 1630, more than one hundred years before the discovery of oxygen. In 1665 Robert Hooke, one of Boyle's pupils, published a treatise showing that heating certain combustible materials either in air or mixed with niter produced a "shiny transient body which we call flame, which is nothing but a mixture of air and volatile constituents of combustible bodies acting upon each other as they ascend." Nine years later John Mayow, also a pupil of Boyle, advanced the theory that two things are necessary for combustion, namely flammable particles and aerial particles, which are so hostile that they enter into sharp conflict when suitably brought together, whereby they are thrown into violent motions resulting in the appearance of fire.

In retrospect it would seem that, had it not been for his death at the age of thirty-six, such a brilliant experimenter as Mayow would surely have come to recognize that the aerial particles which he postulated were a part, but not all, of the air, and that combustion was not an interplay but the actual combining of the two kinds of particles. Unfortunately no one appeared, either among his contemporaries or immediate successors, to reflect his teachings, and another view of combustion known as the Phlogiston Theory became prominent until the middle of the eighteenth century.

This alchemistic notion that combustible substances contained the ponderable principle phlogiston, which, on rapid escape, caused the appearance of fire, was doomed by the discovery of various pure gases. In 1775 Black discovered CO_2 and showed that it was present in small amounts in the air. Between 1767 and 1777 Priestly and Scheele discovered several new gases, each having properties different from air, and laid the foundation for modern gas chemistry, incidentally providing Lavoisier with material to disprove the Phlogiston Theory, and enabling him to substitute therefor the oxygen theory of combustion which has since been amply verified.

In the first decade of the nineteenth century John Dalton made two contributions of importance in the field of combustion, namely the atomic theory and the discovery that explosions of certain mixtures of methane and ethylene with oxygen produced carbon monoxide and hydrogen rather than carbon dioxide and water. This latter observation seems to have been overlooked for the ensuing eighty years during which theories involving the preferential oxidation of hydrogen in hydrocarbons flourished.

In the second decade of the nineteenth century Sir Humphry Davy found that there are certain fairly definite limits of explosibility for each flammable gas when mixed with air or oxygen, and that the stimulus required to produce ignition varied in intensity from mixture to mixture. A great many similar determinations of the limits of flammability and of so-called ignition temperatures have since been made.

Since Davy had deduced that a certain temperature was required to ignite a specific explosive mixture, it was logical to assume that a continuous transfer of heat to the unburned gas ahead of the flame was essential to its propagation. Thus, when confronted with the problem of accidental explosions in mines, he saw the desirability of interposing between the most probable source of ignition and the bulk of the gas in the mine some material which would effectively reduce the quantity of heat flowing from the burned to the unburned gas, and thus extinglish the flame near the source of ignition. He found experimentally that small tubes, particularly if they were good thermal conductors, did actually accomplish this purpose in mixtures obtained from mines. From small tubes to wire gauze was a logical step, and the Davy Safety Lamp resulted. This invention, which in his own words consisted "in covering or surrounding the flame of a lamp or candle by a wire sieve," is one of the first important practical results of combustion research.

Davy's subsequent work included the first recorded studies of the temperatures of flames and of catalytic combustion, both of which are still very live subjects of investigation.

The period from 1836 to 1880 has been frequently called the Bunsen era because it was so completely dominated by the influence of this great chemist and his pupils.

Among the more important contributions of Bunsen are the perfection of methods for quantitative analysis of gases, the application of such methods to mixtures of gases in the blast furnace, which resulted in one of the greatest advances in scientific metallurgy, and the development of the gas burner which still bears his name. Some of his other reports contained the first recorded measurements of flame speeds and of maximum pressures developed during explosions in closed containers, with the flame temperatures calculated therefrom. All of these measurements have been repeated at subsequent intervals as improved methods were devised and as new sources of error were revealed.

As is always the case during a period

of rapid advance, there appeared during the Bunsen era a number of theories which later had to be discarded. Most conspicuous were those which postulated the preferential combustion of hydrogen and which led to the conclusion that the law of mass action did not apply to gaseous explosions. Many investigators were misled because they were not aware of the possible effects of water vapor and of catalytic reactions, of which the latter may be a function of the particular apparatus. Unfortunately, these same pitfalls are not always avoided even to-day.

However the studies of explosions themselves, together with important contributions in related fields, such as Deville's investigations of thermal dissociation and accurate determinations of heats of combustion by Berthelot, Julius Thomsen and others make the Bunsen era stand out as the period during which was laid the real foundation for modern theories and endeavors in the field of combustion.

Definition and Discussion of Terms

Before proceeding further it may be well to pause for a brief discussion and, where possible, a definition of some of the terms which will be used most frequently in what is to follow. A number of these terms may be defined specifically, while many others do not seem to have universally accepted meanings. So far as is known the following definitions are comparatively free from serious objection.

1. *Flame* is gas rendered luminous by combustion or heating.

2. The *flame front* is the boundary surface between the luminous region and the dark region of unburned gas.

3. The *reaction zone* is the region of inhomogeneity in which homogeneous unburned charge is transformed into combustion products in chemical equilibrium.

4. The *spatial velocity* of the flame is the velocity with which the flame front moves in a direction normal to its surface, relative to a fixed point in the explosion vessel.

5. The *transformation velocity* is the velocity at which the flame front advances into the unburned charge in a direction normal to its surface, that is, the linear velocity with which the unburned charge is transformed chemically.

6. The *gas velocity* is the velocity with which the flame front is transported bodily in a direction normal to its surface by mass motion of the gases into which it is advancing.

7. The *expansion ratio* is the ratio of the volume of the same mass of gas before and after explosion at constant pressure.

Numerous other terms such as the limits of flammability, flame temperature and ignition temperature, the latter often further described by prefixing the words self, auto or spontaneous, are frequently used in connection with certain burning characteristics. Most of these characteristics have real practical importance, and specific definition of the terms used to describe them would be of great value. Unfortunately this has not been possible because the numerical values which have been determined are not as yet entirely independent of the apparatus in which the measurements were made, and arbitrary experimental methods have not been generally adopted.

The Modern Period

In a review of that phase of combustion research which was selected for this report it is convenient to consider the advances of the last sixty years without further regard for chronology. Instead, some additional subdivisions of the field will be made and each will be treated separately. As a first step, a distinction may be drawn between the cases in which the flame is stationary and those in which it is in motion, as is usual during explosions.

Stationary Flames

The two general classes of stationary flames are the diffusion flame, in which the mixing of the fuel and oxygen takes place in the flame itself, and the Bunsen-

type flame, in which the mixing has been accomplished before the mixture enters the flame.

Diffusion flames. Common examples of this type are flames from a burning candle, oil lamp, wood or coal. As the name implies, the characteristics of the diffusion flame are largely dependent upon the rate at which the mixing of fuel and air is accomplished in the neighborhood of the flame. The inter-diffusion of the vaporized combustible and the oxygen to form an explosive mixture is so much slower than the rate of the reaction that the latter is of only secondary importance. Therefore diffusion flames, despite their wide variety of practical applications, are not promising subjects for the study of the combustion process.

Burke and Schumann[3] evolved equations which are in fair agreement with the observed facts for diffusion flames obtained by passing gaseous fuel and air separately, and at the same linear velocity, through coaxial tubes. By these equations the effects of such factors as gas velocity, nature of the fuel and mixture ratio, upon the size of the flame, may be calculated. However, they involve coefficients of diffusion under the somewhat uncertain conditions prevailing close to the flame.

Bunsen-type flames. In the Bunsen burner, in most domestic gas appliances, and in various welding torches the fuel and air are proportioned and mixed before reaching the opening or port of the burner. Such devices are designed to burn the unconfined mixture with a flame which has more or less stability in the surrounding atmosphere. Stability is achieved by adequate control of the proportion of fuel to oxygen and of the rate at which the mixture issues from the burner port.

The velocity of flow through the port (S_m) must exceed the transformation velocity (S_t) to prevent the travel of the flame back through the port and into the mixing chamber, an occurrence commonly known as flash back. The mixture velocity may be several times the flame velocity, but above a certain ratio the flame is blown off the port. Thus the characteristics of the Bunsen flame of any mixture are largely dependent upon the rate at which it is transformed by flame, and studies of such flames may yield values of transformation velocity.

Some of the necessary concepts may be introduced by considering a hypothetical case in which it is assumed that a homogeneous explosive mixture flows without turbulence through a burner tube whose walls offer no resistance to gas flow and neither absorb nor conduct heat.

If, in such an ideal burner, the mixture velocity S_m is sufficiently greater than the transformation velocity S_t, a flame of the familiar Bunsen type with its inner cone and outer mantle may be established above the burner port, as shown diagrammatically in Fig. 1 (a). Upon decreasing the mixture velocity the height of both cone and mantle would also decrease until finally the cone approached a plane surface, which would then move down the tube as such. For a single value of S_m the flat flame could be held stationary, with a small mantle persisting at the burner port, as illustrated in Fig. 1 (b). At such a steady state the mixture velocity S_m would be identical with the gas velocity, S_u, as defined, and these velocities would be equal in magnitude but opposite in direction to the transformation velocity S_t.

Thus, in the hypothetical case, only the measurement of the linear rate of flow of the unburned mixture through the frictionless tube is needed to establish the value of transformation velocity. However, in an actual tube the gas velocity is not uniform, but varies from

[3] S. P. Burke and T. E. W. Schumann, *Indust. and Engineering Chem.*, 20: 998–1004, 1928.

practically zero at the walls to a maximum at the center, so that a plane flame can not be obtained by reducing the rate of flow. Further irregularities in the shape and position of the inner part of the flame also arise from heating the walls. Both of these difficulties can be overcome to a considerable extent if the inner cone is allowed to rest on the port of a burner, through the tube of which the gas flow is laminar, provided that proper account is taken of the shape of the actual cone.

Bunsen[4] made the first recorded measurements of the speed of flame by gradually decreasing the measured velocity of an explosive mixture through an orifice to such a value that the flame just flashed back. Modifications of this method have been used by many investigators ever since.

The flash-back method of Bunsen was not accurate because of the variation in gas velocity over the area of the port. Later Gouy[5] attempted to determine the product of the gas velocity and the sine of the angle between the side and axis of the cone, but found that the actual cone of flame departed so much from a geometric cone that there was no single, definite angle to measure. It was a logical step to consider that the speed of flame could be found by dividing the volume rate of flow through the port by the area of the cone of flame. Subsequent measurements showed that results obtained by this method involved uncertainties which could be largely eliminated by taking proper account of the velocity distribution over the area of the port.

Stevens[6] calculated transformation velocities from measured values of gas velocity and photographs of the flame cone, upon each of which he constructed a geometric cone having the diameter of the burner port as a base and having sides parallel to the flame surface at that point where the velocity of the gas mixture was equal to the mean velocity over the area of the port. His results with this procedure were in substantial agreement with those obtained by an independent method.

Smith and Pickering[7] modified Steven's treatment of the flame photographs by measuring directly the angle between the surface and the axis of the cone of flame at the points of average velocity; that is, at 0.7 the distance from the axis of the port. In a later report, Smith[8] makes the following statements concerning the determination of transformation velocities by the burner method:

1. The numerical result is independent of the velocity of flow of the mixture, so long as the flow is laminar.
2. The result depends upon the size of the port, especially if the area of the flame is used in the computations.
3. Results based on appropriate measurements of angle appear to be a more reliable index of flame speed than those based on area.
4. Maximum speed mixtures give minimum errors and are least objectionable for comparisons between fuel gases.
5. Although burner methods of measuring flame speed are relatively simple and the results directly applicable to a multitude of burner problems, the field of usefulness of the method appears at present to be considerably restricted.

Lewis and von Elbe,[9] in summarizing the possibilities and limitations of the burner method for determining transformation velocity, express their impression that not all of these have been thoroughly explored as yet. In addition to values of transformation velocity, Bunsen-type flames have been used in obtaining information concerning both the

[4] W. A. Bone and D. T. A. Townend, *op. cit.*, p. 39.

[5] M. Gouy, *Annales de Chemie et de Physique*, 18: 27, 1879.

[6] F. W. Stevens, *Technical Report No. 305*, Nat. Advisory Committee for Aeronautics, 1929.

[7] F. A. Smith and S. F. Pickering, *Jour. of Research of Nat. Bureau of Standards*, 17: 7–43, 1936.

[8] F. A. Smith, *Chem. Reviews*, 21: 389–412, 1937.

[9] B. Lewis and G. von Elbe, *op. cit.*, p. 205.

composition of the interconal gases and the temperatures which are attained upon burning various combustible mixtures.

The methods of spectroscopy have been successfully applied in the measurements of the temperatures attained in both Bunsen-type[10] and explosion flames.[11] Light from an electrically heated filament or strip is passed through the flame, colored by a trace of a salt of an alkali metal, usually sodium, and the combined radiation from lamp and flame is observed with a spectroscope. At filament temperatures below that of the flame the sodium spectrum shows the bright lines of emission. Upon increasing the filament temperature beyond that of the flame, the sodium lines become dark lines of absorption. The temperature of the filament at which the change from emission to absorption takes place is the temperature of the flame gas through which the external light is passed. It is thus logical to call this method of measuring the temperature of the inflamed gases the spectral line reversal method.

By its use much information has been obtained on the temperature gradients existing throughout the volumes of various flames, and more on the highest temperatures which are produced with different fuels, together with the effects of mixture ratio and rate of heat production upon these maximum temperatures.

Explosion Flames

For the purposes of this discussion, explosion flames, as distinguished from stationary flames, include all those which spread throughout the available explosive mixture from a source of ignition. With the exception of a few cases in which it is only necessary to decide whether or not there has been an explosion, the great majority of investigations involving explosion flames have required means for measuring the time rate of displacement of the flame from the point of ignition.

The most widely used, as well as the most useful method for determining spatial velocity is by direct photography on a film moving at a known speed. Such a picture not only serves as an accurate time-displacement record of the flame front, but also provides for a visual study of the whole flame movement. This method is generally used except in cases where insufficient light is emitted during the burning and where the introduction of a window through which the flame may be photographed is not practicable.

For flames of relatively low actinic light, the shadow and schlieren methods of photography[12] are available. Both of these utilize the effect of the sharp difference in optical properties existing at the flame front upon light from an external source. The schlieren method has the additional advantage that it indicates the progress of the pressure waves through both the unburned and burned gases.

If it is not feasible to use a transparent window in an explosion chamber, ionization gaps which break down[13,14,15] or small wires which fuse[16] when reached by the flame may be employed. These methods are not appropriate when the flame front suffers irregular changes in velocity between the gaps or wires, but have been used in engine cylinders and in measuring the very high speeds of detonation in long, metal tubes.

In all explosions originating at a point

[10] *Ibid.*, chap 19.

[11] G. M. Rassweiler and L. Withrow, *Soc. Automotive Engineers Jour.*, 36: 125–133, 1935.

[12] B. Lewis and G. von Elbe, *op. cit.*, pp. 149–155.

[13] K. Schnauffer, *Soc. Automotive Engineers Jour.*, 34: 17–24, 1934.

[14] H. Rabezzana and S. Kalmar, *Automotive Industries*, 72: 324–329, 354–357 and 394–397, 1935; *ibid.*, 81: 534–542 and 632–639, 1939.

[15] W. A. Mason and K. M. Brown, *Automotive Industries*, 72: 582–584, 1935.

[16] W. A. Bone and D. T. A. Townend, *op. cit.*, p. 109.

of ignition, the burned and the unburned gas are separated by the flame front. Each elementary layer of unburned gas which is transformed by the flame undergoes physical and chemical changes which always result in a net increase in pressure or volume. Stated in other terms, regardless of whether there is a gain or loss in the total number of gas molecules, the rise in temperature upon burning is always sufficient to produce a net expansion. This expansion affects both the burned and unburned portions of the charge in proportion to their relative volumes. Obviously that expansion which takes place within the flame front must produce an increase in the velocity of the flame front in space by virtue of the outward motion imparted to the unburned gas just ahead of the flame.

Thus the movement of the flame may be likened to that of an airplane flying with a wind, the "wind" during an explosion resulting from the expansion upon burning. The speed of flame in space, like the ground speed of the plane, is the resultant of the speed in quiescent gas, or the transformation velocity, and the "wind" velocity, or speed with which the "wind" transports it bodily forward.

If a quiescent, homogeneous explosive mixture is ignited at a point, the flame begins to spread as a sphere with its center at the point of ignition.[17] It grows in diameter, maintaining the spherical shape, as long as the outward movement of the unburned gas is purely radial. The spherical shape can persist throughout the entire combustion only if the explosion vessel is a sphere with central ignition. For all containers in which some parts of the wall are nearer the flame front than others, the motion of the unburned gas will, at some stage of the burning, begin to vary from radial, and subsequently depart therefrom at an increasing rate.

[17] B. Lewis and G. von Elbe, *op. cit.*, pp. 146–147.

Thus it is fairly obvious that the direction in which the unburned gas will move ahead of the flame front, and consequently the shape of the flame front itself, must be a function of the shape of the vessel. Ellis[18] has taken a number of beautiful successive snapshots of flame during explosions in vessels of various sorts. These furnish visible proof of the principle that the flame front always tends to assume the same shape as the container.

Most photographic records of the initial stages of explosions show that, for a brief interval following the passage of the igniting spark, the flame front has a positive acceleration in space, which results in a curvature of the flame traces on a film which was moved at a constant speed. The diagram on the right of Fig. 2 shows this early period of flame travel on a magnified scale.

The straight portion of the flame trace SF may be extended until it intersects at point A the axis SD, drawn through the spark S. The time interval SA is the increase in the duration of the explosion caused by the initial slow movement of the flame and will be termed briefly the "delay."

The curve of Fig. 2 shows that the delay increases greatly as the concentration of water vapor is reduced in equivalent mixtures of carbon monoxide and oxygen, initially at atmospheric pressure. Reducing the pressure at constant water-vapor concentration also increased the delay markedly, but quantitative measurements are difficult because of the decrease in the actinic light emitted by the explosions.

The real significance of the delay is not fully understood. The low initial speeds of flame in space appear to result chiefly from subnormal values of expansion ratio or transformation velocity, or both, which in turn appear to be asso-

[18] O. C. de C. Ellis and W. A. Kirkby, "Flame," London: Methuen and Company, 1936.

ciated with the establishment of an equilibrium depth and structure of the reaction zone. The flame front must travel a distance at least as great as the depth of the reaction zone before an equilibrium structure can be established.

Pending the development of a satisfactory method for measuring either expansion ratio or transformation velocity in the very early stages of the burning, the causes of the delay period can not be fully demonstrated.

Explosions in soap bubbles. One of the simplest methods yet devised for determining transformation velocity is the soap-bubble or constant-pressure method developed by Stevens.[19] He filled soap bubbles with explosive mixtures, fired them with sparks at their centers, and photographed the resulting explosions.

High speed motion pictures of a bubble explosion[20] show that the spark produces a tiny sphere of flame which grows steadily in size, maintaining its spherical form, until all the mixture is inflamed. The soap film breaks and collapses downward before the burning is complete, so that the explosion runs its course at the essentially constant pressure of the atmosphere surrounding the bubble.

For analytical purposes the explosion in the bubble was photographed through a narrow slit which left its horizontal diameter visible. The film was carried on a drum rotating at a known, constant speed about an axis parallel to the slit. As the diameter of the flame increased, its lengthening image moved along the film and produced a V-shaped trace which constitutes a time-displacement record of the flame front, a typical example of which is shown in Fig. 3.

For most mixtures the sides of the V are practically straight, showing that the flame front travels at constant speed. This speed in space, S_s, can be calculated from the angle, α of the V, the known speed, F, of the film, and the ratio, m, of an actual distance to the corresponding distance on the film, through the relation

$$S_s = mF \tan \frac{\alpha}{2}. \qquad (1)$$

The maximum diameter attained by the sphere of hot gases may also be obtained from the film. The ratio of this final volume of the burned products to that of the original bubble is the expansion ratio, E, for the mixture when burned at constant pressure. If r is the radius of the bubble before firing and R is the final radius of the burned gas, as measured on the film, then

$$E = \frac{(mR)^3}{r^3}. \qquad (2)$$

The transformation velocity, S_t, is merely the quotient $\frac{S_s}{E}$, as could be shown if space permitted.

A careful investigation of the possibilities and limitations of the soap-bubble method[21] led to a number of refinements in the apparatus and procedure which improved the accuracy of the results considerably. Values of transformation velocity and expansion ratio were measured for various mixtures of CO and O_2, and for these mixtures diluted with argon and helium.[22]

The results show that the maximum value of transformation velocity occurs slightly on the rich side of chemical equivalence, but that values of E change very little in the neighborhood of equivalence. Argon and helium have practically the same effect on expansion ratio, but a given volume of helium produces less decrease in flame speed than a like volume of argon. The characteristics of the inert gases upon which these effects depend have not yet been definitely identified.

[19] F. W. Stevens, *Technical Report No. 176*, Nat. Advisory Committee for Aeronautics, 1923.

[20] B. Lewis and G. von Elbe, *op. cit.*, p. 147.

[21] E. F. Fiock and C. H. Roeder, *Technical Report No. 532*, Nat. Advisory Committee for Aeronautics, 1935.

[22] E. F. Fiock and C. H. Roeder, *Technical Report No. 553*, Nat. Advisory Committee for Aeronautics, 1936.

The principal advantage of the bubble method is its simplicity, since no measurement of a rapidly changing pressure is involved. Its usefulness is, however, very limited in scope, since no fuel which is soluble in the soap solution can be employed and since control of the concentration of water vapor in the explosive mixture is restricted by the presence of water in the soap film. Because of the nature of the soap film, variations in initial temperature and pressure are also not practicable.

It should be further observed that the measured values of expansion ratio are for the entire burning process, and must necessarily include not only that expansion which takes place in the flame front, but also any which may occur subsequently within the burned gas. Theoretical values of expansion ratio may be calculated from the known thermal properties and equilibrium data on the mixtures which have been studied by the soap-bubble method, if it is assumed that chemical equilibrium has been established in the sphere of hot gases having the maximum diameter. Such calculated values are in essential agreement[23] with the observations.

Explosions in tubes with large surface to volume ratio. The literature records a great many observations of spatial velocity made by firing explosive mixtures in tubes whose lengths were great compared to their diameters. To illustrate some of these results, the series of photographs shown in Fig. 4 was taken, using equivalent mixtures of CO and O_2 containing 2.7 per cent. of H_2O vapor in a glass tube approximately 1 inch in diameter and 20 inches long. In each case the tube was vertical and the lower end was closed. For pictures A, B, C and D, the upper end was also closed. For pictures E and F the upper end was opened to the surrounding atmosphere just prior to ignition, which took place at the lower or closed end in E and at the upper or open end in F. As indicated by the dashed time records (1056 dashes per second) the film speeds were the same for the first five pictures, but only $\frac{1}{8}$ as fast for picture F. The first glance at Fig. 4 shows that one of the principal difficulties encountered in the study of explosions in tubes is the vibratory character of the flame motion.

In all of the flame records shown, the speed of the flame is low compared to the velocity of sound, so that the pressure gradients which can exist are local in character and comparatively small. The effects of changes in temperature and total pressure upon transformation velocity are likewise small until long after the vibration has begun. Therefore the only factor which can decelerate the flame in space is a reduction in the velocity of the unburned gas away from the point of ignition. It is believed that, for the closed tube, such a reduction in gas velocity, and in picture A even a complete reversal in the direction of motion, may have been produced in the following manner.

Prior to the start of vibration, the expanding flame initiates a pressure wave which outdistances the flame front because it moves through the unburned gas with the velocity of sound. This pressure wave is reflected back from the upper end of the tube and returns to meet the flame. As soon as this pressure front enters the burned gas its velocity undergoes a sudden large increase, since the density of the hot gas is about $\frac{1}{10}$ that of the unburned gas. This rapid increase probably accentuates the rarity of the following stratum. Into this rarified stratum, the unburned gas ahead of the flame will expand and thus acquire a backward component which either retards or reverses the movement of the flame front, and the first wave appears in the flame trace.

The amplitude of a given irregularity in the flame trace would thus appear to

[23] B. Lewis and G. von Elbe, *op. cit.*, pp. 321–326.

depend primarily upon the difference in the velocity of sound in the burned and unburned gas, which in turn is a function of the difference in density.

Consider now the effects of initial pressure upon the character of the vibrations, as shown in A, B and C of Fig. 4, for which all conditions were the same except that the initial pressures of the explosive mixtures were 1, $\frac{2}{3}$, and $\frac{1}{3}$ atmospheres, respectively. In the first place, the adiabatic temperature rise in the unburned gas, for any given position of the flame front, increases as the initial pressure is decreased. Secondly, it may be seen from the photographs that the amount of actinic light radiated by the burned gas is less the lower the pressure. This probably means that the temperature of the burned gas is less for the explosions from low pressures, which in turn is to be expected from the longer molecular free path and consequent greater percentage heat loss to the walls nearby.

Thus it appears that, for identical pressures in the explosion vessel, the lower the initial pressure the higher is the temperature of the unburned gas and the lower is that of the burned gas, both conditions tending to reduce the magnitude of the change in the velocity of the reflected pressure wave at the flame front. Thus the amplitude of the vibration of the flame front decreases with initial pressure. Similarly, since the average temperature of the burned gas is less when the initial pressure is low, more time is required for the wave traveling toward the point of ignition to reach this end of the tube and return again to catch and accelerate the flame front. The period of the vibrations of the flame during runs from low initial pressure is therefore greater, as may be seen in the photographs.

Pictures A, B and C also illustrate the fact, already mentioned, that the duration of the delay period becomes greater as the initial pressure is decreased. While in A the flame can be seen to move away from the point of ignition immediately after the passage of the spark, it moves more slowly in B, and in C there is an interval of about 0.001 second subsequent to the spark in which no flame trace is visible even on the original negative.

For picture D, the explosive mixture initially at a pressure of 1 atmosphere, was fired simultaneously at both ends of the closed tube. In this case the time required for the flames to traverse all the charge was approximately half of that required when the ignition was at one end only. The unburned gas appears to have vibrated more or less as a unit, since the crests of one flame trace are about simultaneous with the troughs of the other.

For picture E the tube was filled with explosive mixture to a pressure of 1 atmosphere and the upper end was opened to the surroundings just prior to firing. The only retrogression of the flame front occurred after it had traveled about three-fourths the length of the tube. Since the nearest solid reflecting surface was the ceiling of the room, about seven feet above the open end of the tube, it is probable that the retrogression is the result of the behavior of the tube as an open organ pipe.

For picture F the tube was again filled to a pressure of 1 atmosphere, the upper end was opened, and a spark gap consisting of small nickel wires was introduced. Only these two wires were in a position to disturb the free egress of the burned gas. The film speed was reduced to one fifth that employed for the other records of this series. Vibrations of the flame front are visible throughout the entire flame trace, but in similar records made by igniting the charge with a flame instead of a spark these vibrations do not always appear until later in the burning process. The wires of the spark gap

FIG. 1. DIAGRAMMATIC REPRESENTATION OF BUNSEN FLAMES IN A HYPOTHETICAL BURNER.

may therefore have been responsible for the early vibrations in picture F.

The general forward velocity of the flame, without regard for the vibration, is, in this case, about 150 cm per second, which, barring wall friction and heat loss, should be the transformation velocity. The actual value of S_t for this mixture, as observed by other methods, is very close to 100 cm per second, thus showing that this particular open-end tube does not give reliable values of S_t.

The reason for the higher flame speeds in the first five pictures compared to that in picture F is, of course, that all the expansion in the former took place behind the flame front and was effective in moving the unburned gas in the direction of the flame travel. However in F the only motion imparted to the unburned gas is that resulting from the reaction of the walls to the escape of the burned gas.

It is hoped that the pictures constituting Fig. 4 have illustrated the major possibilities and limitations of the tube as a vessel in which normal explosions may be observed.

There are many recorded values[24] of flame speed measured in open-end tubes. Such values of spatial velocity have never been sufficiently free from effects inherent in the apparatus to be considered true transformation velocities. This fact is further emphasized by the experimental facts themselves which show that the observed spatial velocity for a given mixture may increase many fold with tube diameter, and that different values are observed when the propagation is in an upward, downward or horizontal direction.

The relative effects of both wall friction and heat loss to the walls decrease as the tube diameter is increased, so that the observed spatial velocities should approach the transformation velocities for large tubes. In such tubes, however, the difficulty of uncertain flame shape is introduced, since ignition is hard to accomplish simultaneously over a large surface.

Explosions in large cylinders and spheres. In any explosion in a closed vessel many complications are introduced by the continuously and rapidly rising pressure. However, much useful information has been obtained by conducting explosions in such vessels without photographing the flame and without measuring the rise in pressure. In most of these experiments it is only necessary to determine whether or not there has been an explosion, and the eye or ear may be adequate.

The more important results of such experiments are (1) the so-called "ignition temperature," or temperature above which the reaction becomes self-propagating; (2) the ignition characteristics, and (3) the concentration limits of the self-propagation of flame.

[24] W. A. Bone and D. T. A. Townend, *op. cit.*, chaps. 11–14.

The spatial velocity of flame in closed containers may be measured by the methods previously described. In such vessels, however, this velocity is highly dependent upon the shape, so that numerical values are of little use unless the movements of the unburned gas can also be determined. An exception should be noted in case all points on the walls of the explosion vessel are at a considerable distance from the spark gap. Soon after ignition in such large containers the spatial velocity attains a constant value which is independent of the characteristics of the container, and is a function only of the expansion ratio and transformation velocity of the particular explosive mixture at the initial temperature and pressure. Practically identical values of the constant spatial velocity of flame in mixtures of CO and O_2 have been observed by the author for explosions in soap bubbles,[25] in a large glass cylinder[26] and in a steel sphere.[27]

When it is desired to follow the entire combustion process from ignition to the walls of the vessel, it is obvious that a spherical vessel with central ignition offers the most promise, since the movements of both flame and gases are symmetrical and may therefore be more readily and more completely analyzed. In other words the spherical container with central ignition seems to offer the greatest chance of minimizing the specific effects of the apparatus in which the burning takes place upon the observed quantities.

Studies of explosions at constant volume are of greatest use only when provision is made for measuring the rapid rise in pressure which results from the burning. Some years ago the primary object of the measurement of explosion pressures was the determination of the mean heat capacities of diluent gases between the initial and final temperatures. Subsequently this method of measuring heat capacity was largely replaced by more reliable spectroscopic methods.

Hence the more recent measurements of explosion pressures have had, as their primary goal, the determination of expansion ratio, transformation velocity, and other quantities which appear to be indices of the power, performance, and economy inherent in the explosive mixtures.

No discussion of explosions at constant volume would be complete without some mention of the pressure indicators which have been used. Those devices yielding pressure-time or pressure-volume data may be classified as (1) optical indicators; (2) balanced-pressure indicators; (3) sampling indicators; (4) micro-indicators, and (5) electrical indicators, according to the principle on which they operate.

In most of these instruments a flexible

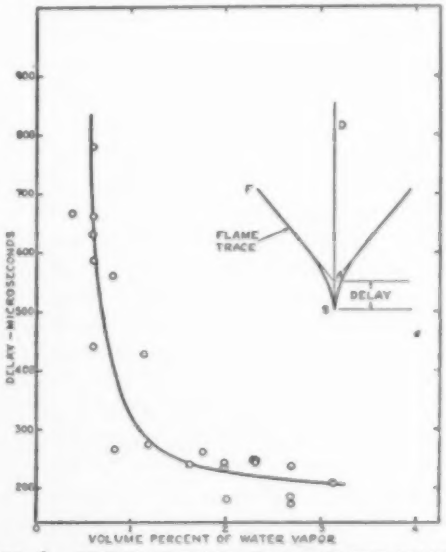


FIG. 2. EFFECT OF WATER VAPOR ON THE DELAY PERIOD IN EQUIVALENT MIXTURES OF CO AND O_2.

[25] E. F. Fiock and C. H. Roeder, *Technical Report No. 532*, Nat. Advisory Committee for Aeronautics, 1935.

[26] *Ibid.*, *Technical Report No. 553*, 1936.

[27] E. F. Fiock, C. F. Marvin, F. R. Caldwell and C. H. Roeder, *Technical Report No. 682*, Nat. Advisory Committee for Aeronautics, 1939.

diaphragm is used as the pressure-sensitive element. Many different methods, both mechanical and/or optical, have been devised for magnifying and recording the motion of the diaphragm. In other types the operation of a light piston or valve shows when the explosion pressure has reached a previously selected and measured value. Still other types make use of the effect of the explosion pressure upon the resistance of an element such as a carbon pile, upon the capacitance of an appropriate condenser, and upon the electromotive force, or more exactly upon the piezo-electric properties of certain crystals such as tourmaline or quartz. In the latter instances a flexible diaphragm usually protects the sensitive element from direct contact with the flame.

In all these instruments a compromise must be made between the time required to accelerate the moving parts and their sensitivity to change in pressure. For example an indicator appropriate for measuring explosion pressures with sufficient accuracy to permit calculation of transformation velocity must have a much higher sensitivity and over-all accuracy than the more rugged instrument suitable for yielding the ordinary engine-indicator cards. The choice of an indicator must, therefore, involve careful consideration of the operating conditions and the required accuracy of the pressure measurements.

Recently a series of measurements[28] using a spherical bomb with central ignition and a window through which the progress of the flame could be photographed, and with six diaphragm-type pressure indicators was conducted at the National Bureau of Standards, using the fuels CO, normal heptane, iso-octane and benzene.

Fig. 5 is a diagrammatic representation of the spherical bomb with its window and of typical flame traces for bomb and soap bubble. When a spark occurs at the center of the bomb, a sphere of flame starts to spread exactly as in the constant-pressure explosion. However, the walls of the bomb soon resist the outward flow of gas set up by the expansion, and the unburned charge is compressed instead of merely being pushed away by the advancing flame front. Thus the expanding gases can not push the flame front outward as fast or as far as in the bubble explosion. As a result of the steadily decreasing outward gas velocity, the flame front travels more slowly as it approaches the walls, even though it is propagating into the compressed and heated unburned charge at an ever-increasing speed.

The slopes of the flame traces shown in Fig. 5 constitute a direct measure of the speeds of flame in space. The slope of the trace of the flame in the bomb gradually decreases from the constant value of that in the bubble until it reaches a value at the wall which is a measure of the transformation velocity in the last portion of the charge to burn. This condition must always prevail since the last of the gas to burn can not move beyond the walls, and is, therefore, essentially at rest when traversed by the flame.

Fig. 6 is a reproduction of a typical explosion record, the fuel in this particular case being benzene. Adjacent to the flame trace is the time record consisting of a series of dashes of known frequency. Beyond are six lines constituting the pressure record. The start of each line indicates the instant at which the explosion pressure reached the value for which an indicator had previously been set. The electrodes at the spark gap photograph as a thin dark line which served as an axis of zero flame displacement. The light streak extending across the figure is a still picture of a fixed slit in the camera, the neon lights operated by the pressure indicators, and the firing

[28] *Ibid.*

spark. This part of the record was made to permit the evaluation of small corrections for lack of alignment. From such simultaneous time-displacement and time-pressure records, a number of the burning characteristics for comparable mixtures of the above mentioned fuels were derived.

In explosions of CO and O_2 the rise in pressure is approximately the same for a given mass of mixture inflamed, regardless of initial pressure. This was to be expected from theoretical considerations since the only difference must result from secondary effects of temperature and pressure upon the chemical equilibrium.

During the early stages of the burning of the three hydrocarbon fuels in theoretical proportions with O_2 there is likewise no measurable difference in the pressure rise produced when a given fraction of the charge is inflamed. Later in the burning small differences do appear in the order of the hydrogen-carbon ratio of the fuels, as might be anticipated from the thermal properties of the products of combustion.

In all the explosions studied there is a general increase in the transformation velocity as the temperature and pressure of the unburned charge rise because of adiabatic compression by the advancing flame.

In the explosions of CO and O_2, for which it was possible to calculate the independent effects of temperature and pressure, both these variables appear to influence the transformation velocity. Some uncertainty in the magnitudes of the effects arises from the possibility that other factors, associated in some obscure way with the stage of the burning, may influence transformation velocities to an unknown extent.

For the hydrocarbons, the transformation velocity is highest for the benzene, and lowest for the iso-octane, with the n-heptane intermediate. Addition of

FIG. 3. TYPICAL RECORD OF AN EXPLOSION IN A SOAP BUBBLE. THE FILM MOVES DOWNWARD; THE FLAME MOVES RIGHT AND LEFT FROM CENTER.

ethyl fluid to the heptane produced no appreciable change in flame speed. Thus there appears to be no relation between transformation velocity under the conditions of the experiments and the tendency of the fuels to knock in an engine. In fact a thorough examination of all the characteristics of normal burning reveals that none can be correlated with tendency to knock. The behavior of all three fuels in the bomb is so nearly the same that high accuracy of the measurements is necessary to show any differences at all in those characteristics which are independent of the apparatus.

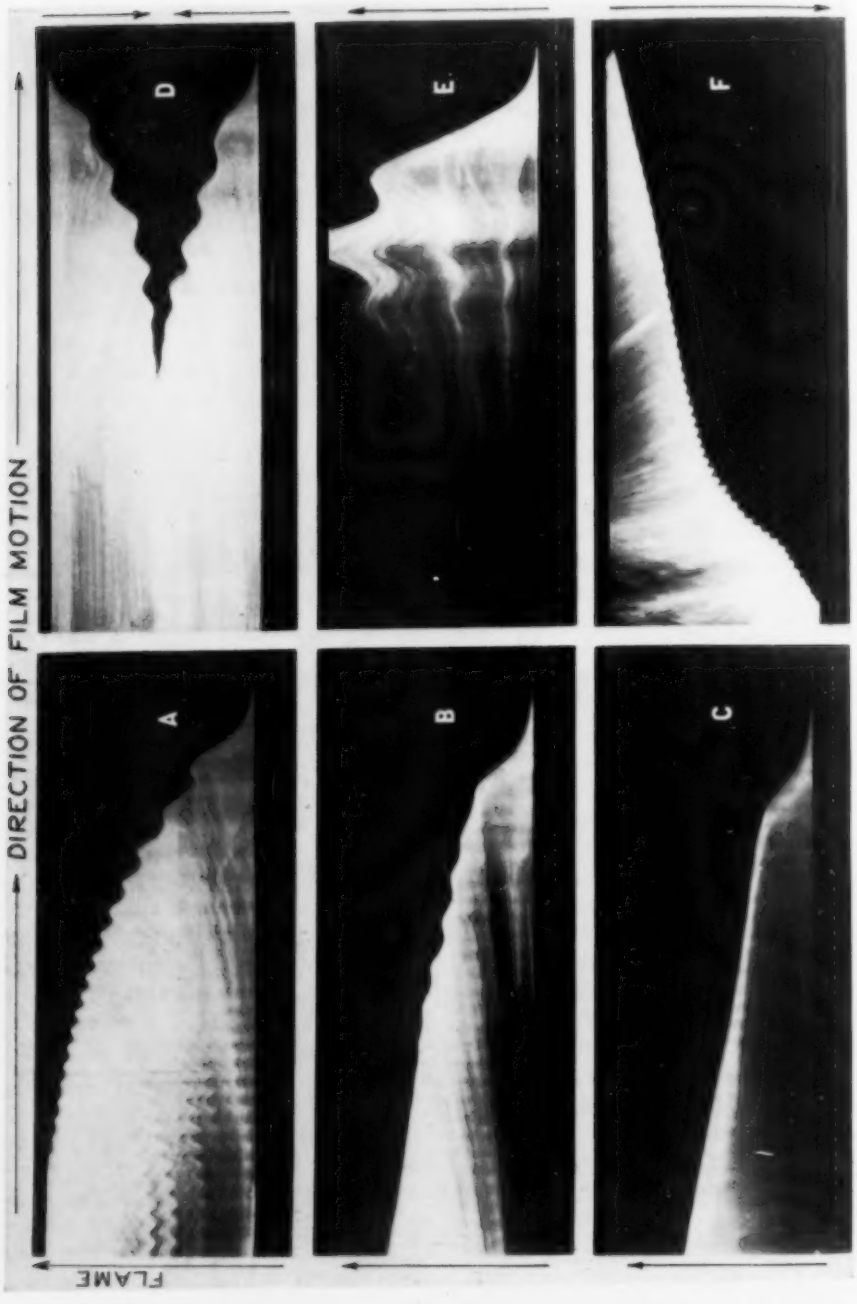


FIG. 4. TYPICAL RECORDS OF EXPLOSIONS IN CLOSED AND OPEN END TUBES.

In all the explosions the rise in pressure for a given mass of charge inflamed was considerably less than would be expected from calculations based on thermal data and the assumption that chemical reaction goes to equilibrium in a very thin reaction zone. The results therefore indicate that the burning is not completed in a shallow zone, but that reaction and heat liberation continue for some time after the flame front has passed.

Further visual evidence of this continued evolution of energy within the inflamed gases, sometimes called afterburning, was obtained by photographing the gas movements within the sphere of flame. In one such experiment eight human hairs, more or less symmetrically spaced with respect to the spark gap, were stretched across the bomb. At the center of each hair, in the line of vision of the camera through the window, a few finely ground particles of black gun powder were attached with very dilute shellac.

Fig. 7 is a photograph of a CO–O_2 explosion with such an arrangement inside the bomb. The hairs seem to offer no resistance to the motion of the flame,

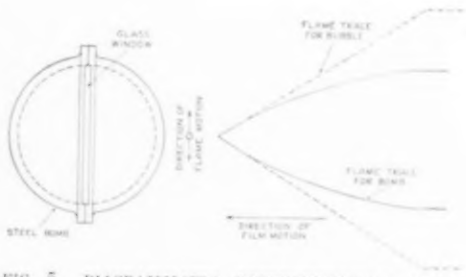


FIG. 5. DIAGRAMMATIC REPRESENTATION OF A SPHERICAL BOMB AND TYPICAL FLAME TRACES FOR BOMB AND SOAP BUBBLE.

while the powder seems to ignite as soon as it is touched by flame, and then to burn very brightly. It can be seen that the hot gases from the powder begin to move at once toward the center of the bomb. This movement continues for some time after the flame has reached the wall of the bomb, as indicated at point A in the photograph. The outward motion of the powder flame in the regions marked B is probably the result of contraction due to cooling at the wall.

There are two possible effects which could cause the flame gases to move toward the center, namely expansion in the gases which surround them, and contraction in the gases which they enclose.

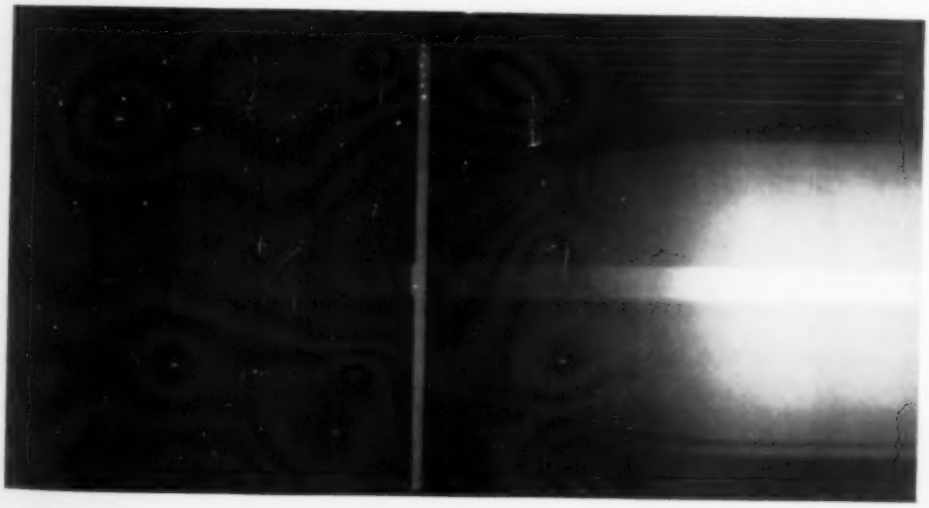


FIG. 6. TYPICAL RECORD OF AN EXPLOSION IN A SPHERICAL BOMB OF CONSTANT VOLUME.

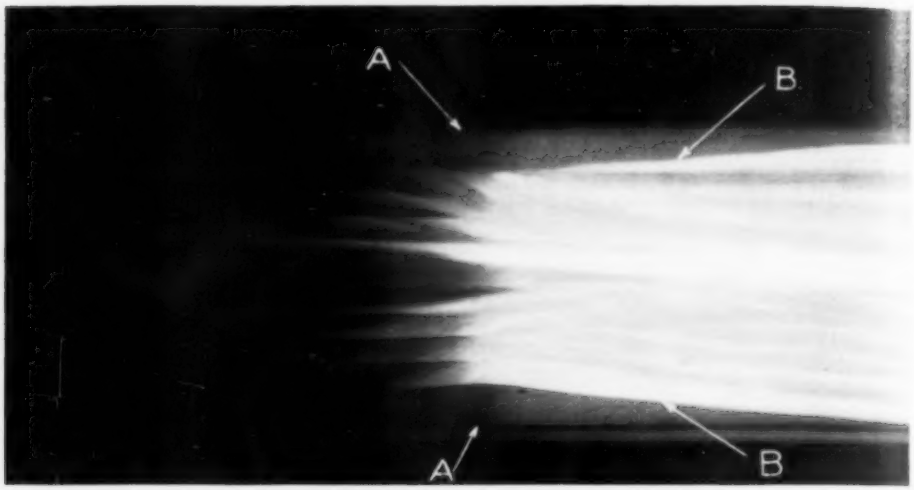


FIG. 7. RECORD OF AN EXPLOSION IN A SPHERICAL BOMB, SHOWING MOVEMENTS WITHIN THE BURNED GAS.

The latter could occur only if the gas near the center were losing heat by radiation at a seemingly improbable rate. It is therefore believed that the continued movement of the flame gases toward the center, after the flame hits the wall, indicates continued expansion in an outer shell of gas which has already been traversed by flame, and that Fig. 7 is thus visible evidence of afterburning. It is further believed that the inward movement of the central flame gas beyond point A can not be due to burning of the powder because such small amounts were used and because the same movement was observed in each of a number of similar explosions where the powder was present at only one instead of eight points.

Lewis and von Elbe[29] calculated values of transformation velocity for ozone-oxygen explosions in a spherical bomb from the time-pressure records alone. These investigators have since referred to a new spherical bomb[30] in which there is provision for taking flame records simultaneously with the pressure records, although actual explosion data with this apparatus have not yet been published.

[29] B. Lewis and G. von Elbe, *Jour. Chemical Physics*, 2: 283–290, 1934.

[30] B. Lewis and G. von Elbe, *Jour. Chemical Physics*, 7: 197, 1939.

(To be Concluded)

SCIENTISTS LOOK AT ASTROLOGY

By Dr. BART J. BOK and MARGARET W. MAYALL

ASSOCIATE PROFESSOR OF ASTRONOMY AND RESEARCH ASSISTANT, HARVARD UNIVERSITY
HARVARD COLLEGE OBSERVATORY

PUBLIC interest in astrology has grown rapidly during the past decade, due in no small measure to the general misapprehension that exists in the minds of many about the standing of astrology as a "science." Astrologers have made skilful use of this confusion and, by the use of pseudo-scientific terms, have succeeded in gaining some degree of public respect. It is significant that it is a general practice on newsstands to place sound popular scientific and engineering journals on the same shelf as the astrological magazines. The confusion is not limited to the less-educated sections of our population; a few months ago one of the country's foremost public libraries gave in its monthly bulletin a list of recent acquisitions in astronomy and astrology in a section headed "Science." There is hardly an astronomer who has not been approached on more than one occasion with a request for the preparation of a horoscope.

What have scientists done to correct such misconceptions? Individuals have occasionally voiced a protest, but active concern in the spreading of astrology has generally been considered below the dignity of scientists. Yet it can hardly be denied that it is one of the functions of scientists in a democracy to inform the public about the nature and background of a current fad, such as astrology, even though to do so may be unpleasant.

Astronomically minded members of the Boston and Cambridge Branch of the American Association of Scientific Workers, aided by some of their colleagues in other parts of the country, recently formed a committee for the investigation of astrology, with B. J. Bok, *chairman*, and Mrs. M. W. Mayall, *secretary*. This committee is releasing simultaneously with this issue a first report in which a general survey is given of several problems related to astrology. We present here a summary of the report, covering such topics as the accepted techniques of astrologers, the history of astrology, the extent to which it has spread, the attitude of scientists, and the legal aspects of the problem.

I. THE HOROSCOPE AND ITS INTERPRETATION

In the technique usually employed by astrologers the horoscope of an individual at the time of his birth plays an all-important role in astrological predictions. Figs. 1 and 2 show how such a horoscope is prepared. Fig. 1 shows how the horizon and celestial meridian divide the celestial sphere for a particular location into four equal parts. Each quarter section of the sphere is again divided into three equal sections by great circles passing through the north and south points on the horizon. The twelve sections thus formed are called "houses" and the points of intersection of their boundaries with the ecliptic are called the "cusps." The exact location of the houses and the cusps in the horoscope of a given individual can be determined only if the time of birth and the longitude and latitude of the place of birth are all accurately known. Comparatively small errors in these basic data

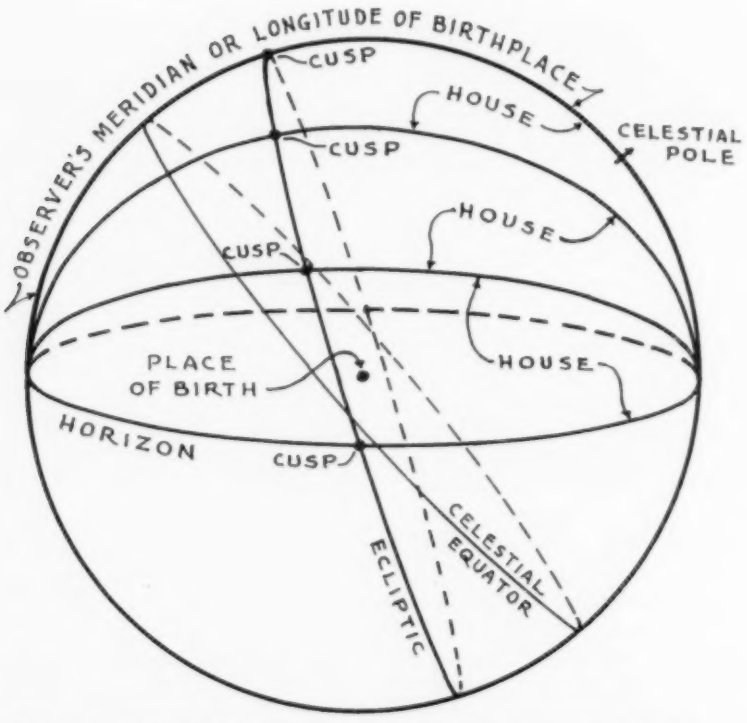


FIG. 1. CELESTIAL SPHERE DIVIDED INTO TWELVE PARTS
THE TWELVE SECTIONS FORMED BY THE GREAT CIRCLES ARE CALLED "HOUSES," AND THE POINTS OF INTERSECTION OF THEIR BOUNDARIES WITH THE ECLIPTIC ARE CALLED "CUSPS."

may have a considerable influence on the relative positions of the planets and cusps.

Fig. 2 is a conventional type of horoscope. The outer circle of the wheel or tire represents the ecliptic and its spokes mark the houses. The houses are numbered as indicated and, with the aid of an astronomical ephemeris, we can now plot the positions of the sun, moon and planets in the houses at the time of birth. The positions of the cusps in the zodiacal constellations are shown by the signs and degrees in the tire.

The interpretation of a horoscope is carried out according to a set of more or less standardized rules, but each expert has developed his or her own system. Each "house" is associated with various matters and each planet, supposedly acting as a center of force, exerts a particular influence, depending upon its position in the horoscope. The relative positions of the planets and their "aspects" play an important part in the interpretation of a horoscope. Standard treatises on astrology, such as the books of Alan Leo, give the significance of each particular aspect, at the time of birth and in later life.

Many astrologers use the system of secondary progressions as the ideal technique of prognostication, according to which each successive day after birth represents a year in the life of a subject. There is, however, considerable disagreement about the value of progressions among leading astrologers of to-day. One of them has stated flatly that "progressions are non-existent."

FIG. 2. CONVENTIONAL TYPE HOROSCOPE OF BIRTH
NOVEMBER 23, 1907. 4 A.M. E. S. T. 40° 43′ N. 73° 58′ W. OUTER CIRCLE REPRESENTS ECLIPTIC AND ITS SPOKES MARK THE "HOUSES." SIGNS AND DEGREES MARK THE "CUSPS."

II. History

The earliest records of astronomy in our Western tradition are of Babylonian origin. The researches of Neugebauer have shown that astrology made its appearance only after astronomy had reached a high level of development. Judicial astrology appeared in Babylonia after 600 B.C., long after the Babylonian astronomers had developed their astronomical tables and ephemerides, calendars and lunar eclipse theory, and long after the discovery of the Saros cycle in solar eclipses.

There existed no judicial astrology during the high periods of civilization in Egypt and it was only during the Hellenistic period, when Egyptian civilization was moribund, that Babylonian astrology was introduced. The Greek astronomers did not concern themselves with astrology until Hellenistic times, when, largely through the influence of Berosus, a school for astrologers was established on the island of Cos.

Ptolemy, the last of the important Greek astronomers, was interested in astrology. Just as Ptolemy's "Almagest" became the standard reference in astronomy, so did the same author's "Tetrabiblos" become the bible of astrology for Islam and the Latin West. Our present-day astrology goes back to Ptolemy. Ptolemy, who flourished at the end of a period of about fifteen hundred years of astronomical development, was apparently the only Greek astronomer of first rank to be connected with astrology.

Astrology threatened to take complete possession of all classes of society in the

Roman world. Cato the Elder and Cicero attacked astrology, but there is no evidence that they had much influence on their contemporaries. Although there were edicts against astrologers, notably in the reigns of Augustus, Domitian and Hadrian, nevertheless their prophecies were feared and they were consulted secretly. The condition is curiously parallel to that which exists in Germany at the present time.

The Roman Catholic Church was vigorously opposed to astrology. St. Augustine, who admitted in his "Confessions" that before his conversion he had been attracted to astrology, was its most articulate and vehement opponent. The opposition to astrology by the Catholic Church has persisted through the ages. The only recorded lapses are toward the end of the middle ages, during the centuries that preceded the birth of modern natural science. The attitude of the Catholic Church is summarized in the words of a modern Catholic writer, who states: "The Catholic Church condemns astrology as a pagan superstition which by encouraging fatalism leads to the denial of Divine Providence."

With the fall of the Roman Empire, astrology came to an end in the West for about five hundred years. The return of astrology in the Latin West came with the introduction of Arabic science in the eleventh and twelfth centuries.

When the Arabs took over Greek science, they also acquired the astrology which had developed in the Hellenistic period; and in the great period of Arabic culture (A.D. 900–1100) astrology became associated with alchemy, medicine, astronomy and mathematics. It has been suggested that most of the Arabic observatories were erected primarily for astrological purposes and that their astronomical use was only incidental, but this has not been confirmed by modern historical research. The main reason for the building of these observatories, including the famous one at Bagdad, was to determine the direction toward Mecca so that the faithful could face it at the hours of prayer.

In the early medieval period, astrology was reintroduced into the Latin West principally through Arabic medicine. It had little influence during the twelfth century, but it went rapidly forward during the thirteenth century and attempted to gain recognition as a "science" by claiming that it was based on cosmological principles. The tolerance of some forms of astrology by church authorities made it possible for astrologers to establish themselves, even to holding professorships in several Italian universities.

During the late Middle Ages and the early Renaissance the opposition to astrology was vigorous, within the church and without, by mathematicians and scientists, including Oresme, Henry of Hesse, Albert of Saxony, and by humanists like Petrarch and Pico della Mirandola. But astrology had gained such a foothold that astronomers were often forced to earn their living by astrology while carrying on their work as best they could. The case of Kepler is an outstanding example. To begin with, Kepler had great difficulty in obtaining an appointment because he was a Protestant and a Copernican but, when he did get a position as lecturer on mathematics at the poor academy at Gratz, one of his duties was the preparation of the yearly almanac containing weather predictions and astrological information. Later, when he was appointed as imperial mathematician at Prague to succeed Tycho Brahe, his financial troubles were not at an end; and in 1628, two years before his death, when his salary was three years in arrears, he took to drawing up horoscopes for the astrologer-soldier Wallenstein as a means of supporting himself and his dependents. Well might Kepler say "Mother Astron-

omy would certainly have to suffer if the daughter Astrology did not earn the bread." In spite of this financial necessity, Kepler kept his astronomical work free from astrology. Tycho Brahe is the only astronomer of the first rank who completely fused his astronomy and his astrology.

The religious revival accompanying the Reformation and the Roman Catholic Counter-Reformation was the most important influence in putting an end to this period of astrology. Astrology still continued to "hang on," as we know from the diatribes of Jonathan Swift, the jibes of Benjamin Franklin and the wrath of Increase Mather against individual astrologers. But its power was broken, and it did not win any marked increase in public interest until our own time.

In this historical summary several interesting points emerge: astrology has flourished in periods of high scientific development rather than in low periods, and likewise in periods when religion and philosophy were in eclipse. Also, astrology has made only practically negligible contributions to science; indeed, its prevalence has been actually harmful. In the middle ages, when students were flocking to astrology lectures, astronomers were having a hard time to earn their living from scientific work. On medicine, astrology had a strangling influence, for physicians gave up diagnosis from the symptoms and case history and relied on horoscopes to tell them why the patient was ill, what drugs to prescribe and what was the favorable time to apply the remedies. Astrology hindered the development of chemistry, because it was only after alchemy had been purged of astrology and other superstitions that chemistry grew as a separate discipline. The most striking fact is that astrology is now trying once more to gain recognition as a science by the use of methods that are reminiscent of those used with success during the middle ages.

ASTROLOGERS' BOOTHS
IN LAHORE, INDIA.

III. Press, Magazines and Advertising

A large percentage of the newspapers of the United States publishes either daily or monthly columns on astrology. These columns might be expected in newspapers sold to the less-educated portion of the population and in the sections of the country where superstition is widespread, but a survey shows that there are hundreds of such newspapers that carry no astrological data whatever. It is in the large centers of population that astrological columns are most prevalent. Most of the public libraries in large metropolitan areas have on file more than a hundred representative newspapers selected from all over the country. On the average about 20 per cent. of the newspapers on file carry astrological columns.

The condition in New York City is more or less typical. Only two out of

"UTRIUSQUE COSMI . . . HISTORIA" ROBERTO FLUD, OPPENHEIM, 1617. TITLEPAGE. A COMPENDIUM OF ASTROLOGY AND MAGIC WITH SPECIAL EMPHASIS ON THEIR USES IN THE DIAGNOSIS AND CURE OF THE ILLS OF THE HUMAN BODY. THE SECTIONS DEVOTED TO ARITHMETIC, GEOMETRY, ETC. ARE OF NO SCIENTIFIC IMPORTANCE. THIS WAS AN IMMENSELY POPULAR WORK AND WAS PRINTED IN MANY EDITIONS.

nine general newspapers published in Manhattan, the *Daily News* and the *Journal-American*, publish astrological columns; but the *News* alone has the largest circulation of all newspapers in the country, about 1,880,000 daily and about 3,380,000 on Sunday, according to 1939 averages. The *Journal-American*, with 609,000 daily, has the largest circulation among the local afternoon papers. Thus the number of readers exposed to these columns is much greater than the proportion of papers (2 out of 9) carrying them would indicate.

Some of the leading newspapers of the country are now printing astrological columns. In the eastern part of the United States the list of distinguished offenders includes the *Philadelphia Inquirer*, the *Times-Herald* of Washington, D. C., and the *Boston Traveler*. In the southeast the *Memphis Commercial Appeal*, the *Charlotte Observer*, and the *Atlanta Constitution* all carry astrological columns. The *News* and the *Plain Dealer* in Cleveland, the *Ohio State Journal*, Chicago's *Herald and Examiner* and the *Daily Tribune* have astrological features. In the San Francisco area two of the four large newspapers carry astrological columns and two do not. Advertisements by astrologers are regularly printed by many of the newspapers that do not refer to astrology in their news sections. Some news syndicates have occasionally released stories with astrological predictions.

The code of standard astrology, to which the great majority of the country's astrologers are supposedly adhering, states that "a precise astrological opinion can not honestly be rendered with reference to the life of an individual unless it is based upon a horoscope for the year, month, day and time of day plus correct geographical location of the place of birth of the individual . . ." This statement alone renders all daily forecasts in newspapers void. The supposedly individual horoscopes that can be obtained by writing in and enclosing twenty-five cents are in reality frequently only copies from a relatively small number of master horoscopes.

The newspapers are by no means the only offenders. Weekly and monthly magazines with a nation-wide distribution have printed articles by leading astrologers. On May 12, 1940, the *American Weekly*—which claims the largest circulation of any magazine in the world—began a series of front-page articles on astrology by "Hollywood's astrologer" Norvell. It is, however, encour-

aging that *Good Housekeeping* has just taken a firm stand against astrology. The Federal Communications Commission has ruled astrologers off the air waves after protest by the American Astronomical Society and the American Society of Magicians.

Hollywood appears to be a veritable astrologer's paradise, and in a quieter way Wall Street has proved a fertile field for astrological activity. Thus it is quite apparent that the influence of astrology is by no means limited to persons with salaries in lower income brackets.

Prominent among the strictly astrological magazines are: *American Astrology*, *Horoscope*, *Astrology Guide*, *Wynn's Astrology*, *World Astrology* and *Astro-Digest*. *American Astrology* is said to have a circulation in excess of 100,000. The average newsstand carries at least four or five different astrological magazines. The dime stores have succumbed to the astrological craze. Modern automatic scales produce tickets with the weight of the victim on one side and astrological advice on the back.

Astrology has made considerable inroads in advertising. The Better Business Bureaus have exposed many of the schemes used by astrologers, but in spite of their effectiveness they have not succeeded in eliminating astrology as an aid to salesmanship.

IV. Legal Aspects

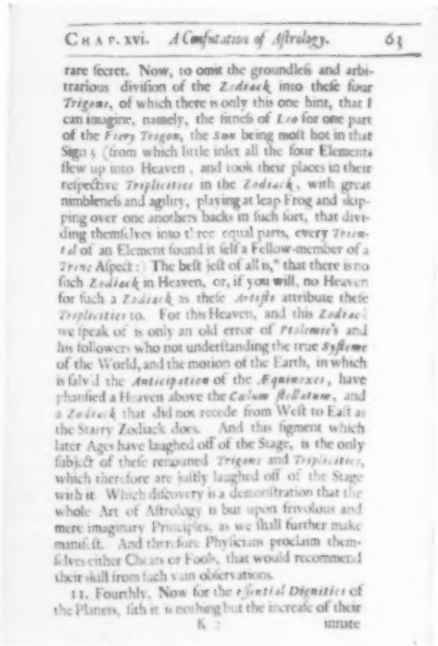
Many states have laws prohibiting the practice of astrology. According to *American Jurisprudence* (Vol. 23, p. 711) "the offense of fortune telling is generally held to be a misdemeanor. Under many statutes fortune tellers are declared to be vagrants and disorderly persons, and it has been said that such persons are without any property rights in a name or appellation, which a court of equity will protect."

In the State of New York the legislature "has signified its disbelief in human power to prophesy human events." "Any prediction of human events for hire is prohibited by subdivision 3 of section 899 of the code of criminal procedure." (253 N.Y.S. 836.) The availability of astrological literature in New York City is proof that these laws are not strictly enforced.

It is evident from the following quotations from the bench that the courts hold no brief for astrology:

Fortune tellers have always been classed with rogues and mountebanks and generally disreputable members of society to be summarily dealt with for the good of the community. (N. Y. *v.* Ashley 184 App. Div. 522; see also 4 Black. Com. 62.)

That as the statute contains no exceptions as to the method employed by defendants, any prediction of future events for hire is prohibited. (People *v.* Malcolm 90 Misc. Rep. 517.)



CHAP. XVI. *A Confutation of Aſtrology.* 63

rare ſecret. Now, to omit the groundleſs and arbitrarious diviſion of the *Zodiack* into theſe four *Trigons*, of which there is only this one hint, that I can imagine, namely, the fitneſs of *Leo* for one part of the *Fiery Trigon*, the *Sun* being moſt hot in that Sign; (from which little inket all the four Elements flew up into Heaven, and took their places in their reſpective *Triplicities* in the *Zodiack*, with great nimbleneſs and agility, playing at leap Frog and skipping over one anothers backs in ſuch ſort, that dividing themſelves into three equal parts, every *Trine* of an Element found it ſelf a Fellow-member of a *Trine* Aſpect:) The beſt jeſt of all is, that there is no ſuch *Zodiack* in Heaven, or, if you will, no Heaven for ſuch a *Zodiack* as theſe *Artiſts* attribute theſe *Triplicities* to. For this Heaven, and this *Zodiack* we ſpeak of is only an old error of *Ptolemie's* and his followers who not underſtanding the true *Syſteme* of the World, and the motion of the Earth, in which is falvd the *Anticipation* of the *Æquinoxes*, have phanſied a Heaven above the *Cœlum ſtellatum*, and a *Zodiack* that did not recede from Weſt to Eaſt as the Starry Zodiack does. And this figment which later Ages have laughed off of the Stage, is the only ſubject of theſe renounted *Trigons* and *Triplicities*, which therefore are juſtly laughed off of the Stage with it. Which diſcovery is a demonſtration that the whole Art of Aſtrology is but upon frivolous and mere imaginary Principles, as we ſhall further make manifeſt. And therefore Phyſicians proclaim themſelves either Cheats or Fools, that would recommend their skill from ſuch vain obſervations.

11. Fourthly, Now for the *eſſential Dignities* of the Planets, ſith it is nothing but the increaſe of their

K 2 innate

A CONFUTATION OF ASTROLOGY

HENRY MORE, LONDON, 1681, P. 63. THE WRITER, A PHYSICIAN, WAS ONE OF THE "CAMBRIDGE PLATONISTS" WHO ATTEMPTED TO FURNISH A PHILOSOPHICAL BACKGROUND FOR THE NEW SCIENCE OF THE 17TH CENTURY.

SUPPLEMENT

TO

PLACIDUS DE TITUS;

CONTAINING

THE NATIVITY OF THAT WONDERFUL PHÆNOMENON,

OLIVER CROMWELL.

Calculated methodically, according to the PLACIDIAN CAPONS,

By the Ingenious

Mr. JOHN PARTRIDGE, M.D.

TO WHICH IS PREFIXED,

PRIMUM MOBILE,

OR

A COMPLETE SET OF ASTRONOMICAL TABLES,

FOR THE

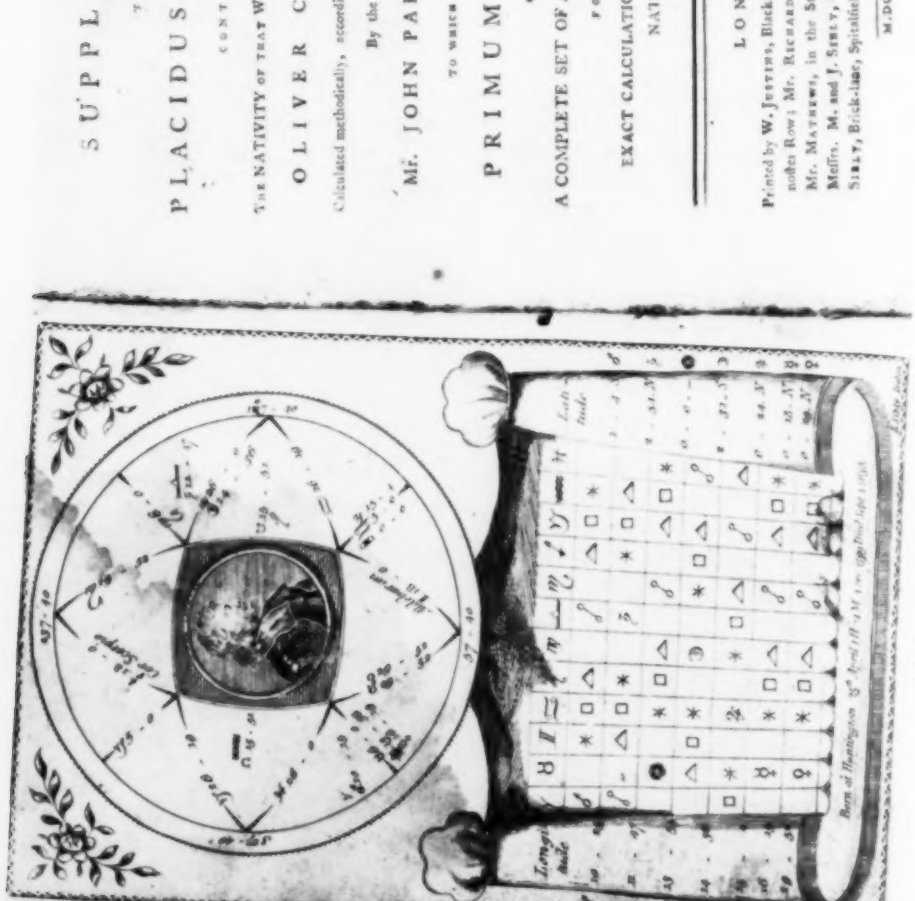
EXACT CALCULATION AND DIRECTION OF

NATIVITIES.

LONDON:

Printed by W. JEFFERIS, Blackfriars; and sold by Mr. BEW, Paternoster Row; Mr. RICHARDSON, under the Royal Exchange; Mr. MATHEWS, in the Strand; Mr. DODSLEY, Piccadilly; Messrs. M. and J. SMITH, Cofwell-ſtreet; and Mr. EDWARDS Sixty, Brick-lane, Spitalfields.

M.DCC.LV.



FRONTISPIECE OF BOOK BY JOHN PARTRIDGE, LONDON, 1730.

THE AUTHOR IS THE ASTROLOGER UPON WHOM JONATHAN SWIFT PLAYED THE FAMOUS JOKE.

"Advertising to tell fortunes by any means is prohibited in some states." (Ruling Case Law, Perm. Suppl. p. 2254.) In addition, the "Printers' Ink Statute" makes false advertising a misdemeanor. The model statute provides that any person, firm or association that places before the public an advertisement of any sort, with intention to sell or in any wise dispose of merchandise, securities, services or anything so offered to the public, which advertisement contains any assertion, representation or statement of fact which is untrue, deceptive or misleading, shall be guilty of a misdemeanor. A study of Postal Fraud Orders shows that astrologers continually make use of the printed word in a manner that is deceptive and misleading in order to increase the consumption of their wares, a practice which this statute was designed to prevent. The Printers' Ink Statute has been "enacted into law in twenty-five states, while thirteen additional states have adopted it with modifications." (Boston Better Business Bureau, Fact Booklet, 1938.)

Astrology is condemned by the courts, and the public can find protection against its practices through existing laws. These laws can and should be enforced, and the enactment of more effective and uniform laws should be urged.

V. The Attitudes of Scientists

Why is it that physical scientists are, apparently without exception, opposed to the teachings of astrology? Studies of the stars and planets have shown above all that the amounts of radiation from these bodies that are received on the earth are exceedingly small and that their gravitational effects are so slight as to be negligible in comparison with those from nearby objects.

Apart from the sun, the moon is the only celestial body that regularly produces a force in excess of the gravitational force produced by adjacent objects at the time of birth. Only under the most favorable conditions can the gravitational attraction of the planet Mars equal that produced by the doctor in charge of the delivery.

The apparent brightness of a star or planet will hardly be more than that of the tail-light of an airplane passing in flight overhead. The walls of hospitals and other buildings where babies are born are opaque to all known radiations from the planets.

Is it possible that there exists some as yet unknown way in which the planets can exert their influence on human affairs? Every one realizes that there are many problems, for example, those presented by hypnotism and thought transfer, that have not yet been explained in a satisfactory fashion. The case of astrology falls outside this class. It is extremely unlikely that the planets, which have a considerable degree of similarity in their general constitution, would affect human affairs according to the generally accepted scheme of astrology. For astrology as it is practiced to-day not only requires an unknown mechanism for the transfer of planetary influence, but it requires further that planets with a considerable degree of similarity should affect human affairs in an entirely dissimilar fashion.

Astrologers attach great influence to the signs of the zodiac. Because of precession of the equinoxes the apparent positions of these signs have shifted by more than twenty-five degrees during the past twenty centuries. It is impossible to understand how the stars can affect human affairs, but it is doubly difficult to suggest a mechanism to account for the influence of the zodiacal signs, which continue to change their position among the stars.

The choice of the moment of birth as the one and only critical instant seems

TEN PERIODICALS ON ASTROLOGY

ARE REGULARLY CARRIED BY THIS MAGAZINE STORE IN HARVARD SQUARE WHERE, ON THEIR WAY TO CLASSES, HARVARD STUDENTS AND PROFESSORS BUY THEIR READING MATTER. SOME OF THESE ASTROLOGICAL PUBLICATIONS SELL BETTER THAN "THE ATLANTIC MONTHLY" AND "THE HARVARD GUARDIAN." NOTE THAT THE ASTROLOGICAL MAGAZINES ARE MOST PROMINENT IN THIS WINDOW.

arbitrary, and one is inclined to ask why this particular moment should be favored over the time of conception or the first exposure to fresh air?

An interpretation of the rules laid down by astrologers demands the existence of an unimaginable mechanism of action. Astrologers have not provided us with as much as a sound hypothesis that might serve as a basis for their speculations. Astrologers attempt to offset this lack of a sound working hypothesis by the introduction of terms and concepts that are unknown to physicists and astronomers. No one, with a high-school training in physics, should be fooled into accepting an explanation of the laws of astrology in which the term "cosmic vibration" figures prominently.

Scientists would feel justified in considering astrology as a legitimate field of scientific inquiry if astrologers could claim that its basic rules had been established through a rigorous study of correlations. But such a study has not been made. The rules by which astrologers interpret their horoscopes have not been derived from any known experiments or observations. Astrologers frequently claim an observational basis in the experience of forgotten generations far back in antiquity, but pure superstition can claim as sound a basis. In the cases of planets discovered in our times (Uranus, Neptune, Pluto) the evidence is conclusive that their influences on men were ascribed by the astrologers before preliminary observational tests of the influences could have been made, and even before accurate orbits could be assigned to the planets.

One might conceivably prove or disprove astrology as it is practised to-day

through a study of successes and failures of predictions based on horoscopes. Such a study would necessarily be of a statistical nature and the results should be subjected to rigorous statistical analysis. The committee has been unable to find anywhere the source material for a decisive test. Those few tests that have been carried out were based on incomplete data about the exact times of birth or the precepts of statistical analysis were not followed with sufficient care.

It is, however, possible to test for certain broad influences assigned by astrologers to specific planets and signs of the zodiac. Farnsworth has studied the zodiacal birth signs of some two thousand musicians and painters. He found that the correlation predicted by astrology—Libra is supposedly the esthetic sign—was absent. A member of the committee has made some similar tests for birth dates of scientists listed in "American Men of Science." The investigation shows that the frequency distribution of birth dates of scientists resembles very closely a random distribution and that the seasonal variations of birth dates resemble very closely those found by Huntington.

The seasonal variations in birth dates are highly significant for such tests. Huntington has shown that about 15 per cent. more people are born in January–February and September than in May–June and November. These seasonal variations are reflected in the separate frequencies for all professions, engineers, industrialists, clergymen, bankers, physicians, chemists and authors. (See Huntington's "Season of Birth," 1938.) Now if instead of months zodiacal sun-signs are considered, the general trend does not change, whereas for astrological influences we should expect widely different correlations for the different professions.

In conclusion, we find that astrologers

WHERE HARVARD STUDENTS BUY THEIR TEXT BOOKS

THE PHOTOGRAPHER FOUND THIS POPULAR BOOK ON ASTROLOGY PROMINENTLY DISPLAYED BETWEEN "THE LIFE OF PASTEUR" AND "THE ANOINTED." AMONG OTHER BEST SELLERS ON THIS SHELF IS A GREAT STACK OF VOLUMES OF "GONE WITH THE WIND."

have failed to suggest a workable mechanism by which the stars and planets can exert their influence on human destiny. The doctrine of astrology can not claim that it is in any way supported by statistical evidence from observed correlations, and until such correlations are established scientists can not accept the precepts of astrology.

VI. Psychologists State Their Views on Astrology

The committee for the study of astrology has been fortunate in having the cooperation of some leading psychologists. At the request of Professor G. W. Allport, the executive council of the Society for Psychological Study of Social Issues authorized the release by the committee of a statement entitled: "Psychologists State Their Views on Astrology." We are glad to present this statement without change.

Psychologists find no evidence that astrology is of any value whatsoever as an indicator of past, present, or future trends in one's personal life or in one's destiny. Nor is there the slightest ground for believing that social events can be foretold by divinations of the stars. The Society for the Psychological Study of Social Issues therefore deplores the faith of a considerable section of the American public in a magical practice that has no shred of justification in scientific fact.

The principal reason why people turn to astrology and to kindred superstitions is that they lack in their own lives the resources necessary to solve serious personal problems confronting them. Feeling blocked and bewildered they yield to the pleasant suggestion that a golden key is at hand—a simple solution—an ever-present help in time of trouble. This belief is more readily accepted in times of disruption and crisis when the individual's normal safeguards against gullibility are broken down. When moral habits are weakened by depression or war, bewilderment increases, self-reliance is lessened, and belief in the occult increases.

Faith in astrology or in any other occult practice is harmful in so far as it encourages an unwholesome flight from the persistent problems of real life. Although it is human enough to try to escape from the effort involved in hard thinking and to evade taking responsibility for one's own acts, it does no good to turn to magic and mystery in order to escape misery. Other solutions must be found by people who suffer from the frustrations of poverty, from grief at the death of a loved one, or from fear of economic or personal insecurity.

By offering the public the horoscope as a substitute for honest and sustained thinking, astrologers have been guilty of playing upon the human tendency to take easy rather than difficult paths. Astrologers have done this in spite of the fact that science has denied their claims and in spite of laws in some states forbidding the prophecies of astrology as fraudulent. It is against public interests for astrologers to spread their counsels of flight from reality.

It is unfortunate that in the minds of many people astrology is confused with true science. The result of this confusion is to prevent these people from developing truly scientific habits of thought that would help them understand the natural, social, and psychological factors that are actually influencing their destinies. It is, of course, true that science itself is a long way from a final solution to the social and psychological problems that perplex mankind; but its accomplishments to date clearly indicate that men's destinies are shaped by their own actions in this world. The heavenly bodies may safely be left out of account. Our fates rest not in our stars but in ourselves.

THE FUTURE OF FORESTRY AND GRAZING IN THE SOUTHERN PINE BELT[1]

By ELWOOD I. TERRY

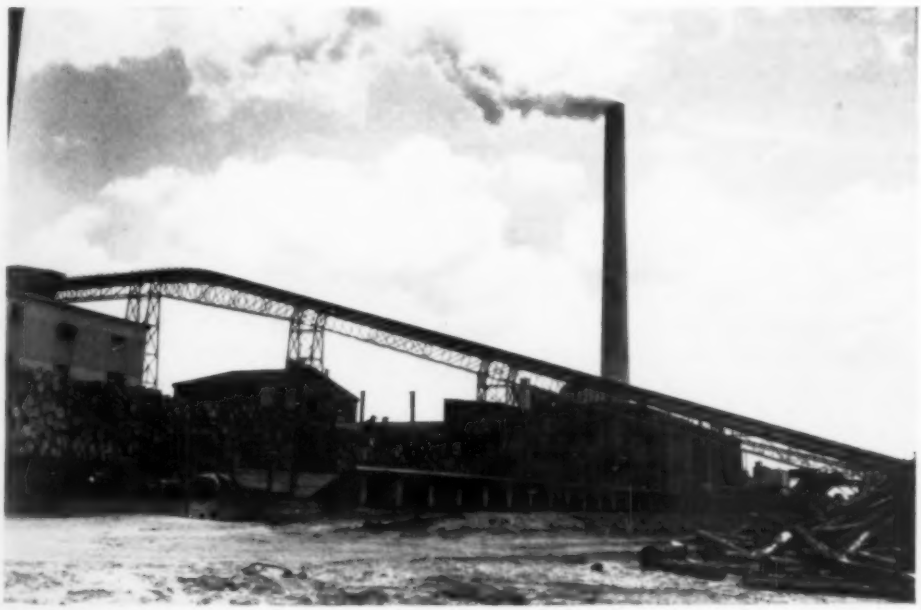
PROFESSOR OF GEOGRAPHY AND CONSERVATION, WINTHROP COLLEGE, SOUTH CAROLINA

THE practice of setting out fire "to improve the grazing" is responsible for most of the woods-burning in the South. Many other causes are often cited, but they are almost inconsequential when compared to the time-honored custom of "burning off the rough." And there are among intelligent live-stock men some warm defenders of that practice. A few years ago an article appeared in a forestry magazine entitled "The Forest that Fire Made" (meaning the Southern longleaf-pine forest), which had nearly the effect of a bombshell exploding in the forestry camp.[2] It was written by S. W. Greene, of the Bureau of Animal Industry, who for a number of years had been connected with the Coastal Plains Experiment Station in Mississippi, studying the effect of ground fires upon forage production in the South.

The point of Mr. Greene's argument was that the great forest of nearly pure longleaf pine which the white man found when he landed upon these shores was the result of repeated ground fires that the Indians were in the practice of setting to clear off the underbrush and make easier the hunting of the deer. This favored the longleaf pine over competing species because of its remarkable resistance to fire in early youth. It survived the light ground fires that killed

[1] Photographs, courtesy of U. S. Forest Service, Southern Region.

[2] S. W. Greene, *American Forests*, October, 1931.



A PULP AND PAPER MILL IN SOUTH GEORGIA

A VIRGINIA LONGLEAF PINE
STAND BADLY FIRE DAMAGED.

the seedlings of shortleaf and loblolly pine and burned back the hardwood "brush." So when De Soto and his men came in 1539 they found an open-growth forest of almost pure longleaf pine stretching from the Atlantic to the Mississippi and beyond, devoid of underbrush and affording an easy highway for them to travel over and drive along their herds of cattle and swine.

Now forest ecologists have always attributed the typical longleaf-pine stands of the Atlantic and Gulf coastal plains to the deep sandy soil on which they invariably grew. The longleaf pine is one of the few trees—and the only important timber tree—that can thrive and grow to large size on such dry sandy sites because of the remarkably long taproot that it develops, often penetrating the soil for fifteen or twenty feet in search of permanent moisture. No other tree of the eastern United States naturally develops such an enormous taproot. Along the rivers which cross the coastal plain, on the moister and richer overflow bottomlands, we find a mixed forest of dense hardwoods and cypress, from which the pine is rigidly excluded. The extensive stretches of deep sandy soil covering the slightly more elevated interfluves are undoubtedly the fundamental natural factor in determining the longleaf type of forest—the "pine barrens" of the pioneers. But the writer agrees with Mr. Greene in believing that the generations or perhaps centuries of ground burning to which the "piney woods" have been subjected have profoundly modified their aspect. Only, while from the viewpoint of the grazing man the change has been for the better, from that of the lumberman it has been for the worse. In his article Greene plainly states: "Without annual grass fires the grasses are smothered out and neither cattle nor quail can long exist in such a forest." And with that statement no one who is thoroughly familiar with the Southern pine forest will care to enter into a controversy. It is as true of the shortleaf and loblolly pine forests as of longleaf.

It should be recognized, however, that Mr. Greene looks at these forests with the apperception of the grazing man. He thinks that fire is responsible for the origin of this type of forest, but his direct interest is not in the timber-producing values of these forests but in their value for grazing. To him the ideal forest is one free from underbrush but carpeted with a heavy growth of grass and so open that a deer may be seen through the timber "as far as the eye can reach." That undoubtedly makes an ideal wooded pasture, but to the lumberman or forester appraising its timber values it is comparable to a ten-acre field of corn in which the mature stalks are so few and far between that a man standing on one side of the field could see a horse trotting along a road on the opposite side.

But we must concede that the early pioneers, in burning off the leaf-litter

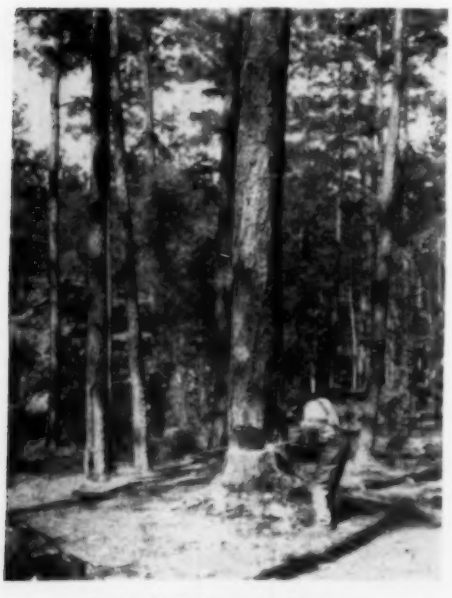
and ground cover, did attain their object. They increased the amount of grass for their stock to feed on. For it is unlikely that much if any grass ever grew beneath the dense canopy of the virgin forest anywhere in the humid eastern part of our country, not even excepting the sandiest soils of the pine barrens. But after the leaf-litter, herbaceous plants and seedling trees have been burned off grass will usually come in, even under fairly thick shade. And if burning is continued year after year, destroying and preventing reproduction, the forest will become more and more open and the grass will grow rank and form a sod, for grass loves the sunlight. In time nothing will be left of the forest but an open grove of overmature, decadent trees, and they will finally disappear.

That is the probable history of the considerable area of "savannas" or open grass lands that the early explorers found frequently intercepting the forest in our Southern states. It was likewise the cause of the low density or open character of the longleaf-pine forest that De Soto rambled over. For as Mr. Greene points out, there is positive historical evidence that the Indians had made a practice of burning over the forest frequently for hunting purposes long before the Europeans appeared. A forest long subjected to recurrent ground fires undergoes profound alteration from its original condition and can not truly be called a virgin forest. If that be the historical fact, then it may be asserted that in all probability no white man has ever beheld the longleaf-pine forest in its primeval state, and has no objective example of what such a forest may be like or the quantity of timber it may produce. Neither does it give any index of the yields of forest products that may be obtained under good forest management, with fire and grazing precluded. But, in this warm humid region with great natural capacity for tree growth, the long-continued ground-burning is undoubtedly responsible for the open nature of the forest with its slow rate of growth and pitiably small yield of timber, seldom exceeding four or five thousand board feet per acre. And most of the trees composing those stands are two hundred years or more old. In the Pacific Northwest old-growth Douglas fir often averages a hundred thousand board feet per acre over extensive areas, and the virgin forests of the Northeast and the Lake States gave far heavier yields than the Southern pine.

But nearly all the Southern pine forest has been cut over at least once, and fully three fourths of the area that is now in some stage of forest growth is covered with second-growth timber, which has repossessed the land following the removal of the original stand. From now on we must depend upon "second growth" if the forest industries are to be perpetuated. But at what rate are

13-YEAR OLD LONGLEAF PINE
REPRODUCTION ON THE CHOCTAWHATCHEE NATIONAL FOREST, FLORIDA.

TURPENTINED LONGLEAF PINE
BADLY FIRE DAMAGED. NOTE OPENNESS OF STAND AND ABSENCE OF YOUNG GROWTH. WESTERN FLORIDA.



SELECTIVE CUTTING
IN OLD GROWTH YELLOW PINE IN SOUTH CAROLINA. THIS TREE IS ECONOMICALLY MATURE AND ITS REMOVAL WILL PERMIT INCREASED GROWTH IN THE SMALLER TREES.

these second-growth forests, which have been subjected to ground fires and grazing, reproducing a timber supply?

The Forest Service has just completed its forest survey, or stock-taking, of the timber resources of the lower South, and finds that over most of the longleaf-pine belt the average stand per acre is about 1,500 board feet of saw-timber and 2.7 cords of wood in trees of less than saw-timber size. If the whole stand were cut for pulpwood it would make only 6 or 7 cords per acre. That is a miserably low yield, and it would not pay to grow such stands under forest management. Compare it with yields of second-growth white pine in the Northeast, where stands fifty to sixty years old often yield 50,000 board feet to the acre, or with the "cultured" spruce forests of central Europe, where yields of 140,000 board feet per acre are regularly obtained, and that on soils which are naturally no more fertile than those of our Southern pine lands. Such high yields may never be produced by longleaf pine even under the most favorable conditions, but yield tables for our Southern pines recently compiled by the Forest Service show that fully stocked stands of longleaf may be expected to yield 45,000 board feet of timber per acre in an eighty-year rotation, or forty cords of peeled pulpwood per acre in forty years, and fifteen cords in twenty years. Shortleaf, loblolly and slash pines all produce considerably higher yields. These four Southern pines are all valuable timber species and as a group rank among the most rapidly growing timber trees of the United States. Longleaf and slash pine, yielding crops of both turpentine and timber, are the famous "dual-purpose trees." All four species can be used for making the kind of paper pulp from which "kraft" paper is manufactured. That is the brown paper used for wrapping packages and for paper bags, and the same pulp is also used for making cardboard, the fiber-board cartons and many

other articles. The South has already captured the kraft-paper industry. More than forty mills are now in operation in this region, making either the pulp only or both the pulp and finished paper products. Between Virginia and Texas at least sixteen new mills have been built during the past two years. For 1938 the consumption of pulpwood was estimated to be between six and seven million cords.

The lumbermen throughout the South are panic-stricken over the rivalry they are encountering from the pulp mills for raw material. And now that the experiments of the late Dr. Charles Herty indicate that a good grade of newsprint can be made at low cost from Southern pine, the prospects are excellent for a general migration of the newsprint-paper industry to the Southern states within the next decade or so. That will surely eventuate if the paper manufacturers can be assured of a permanent supply of pulpwood for their mills. But can they? What will be the drain on the Southern pine forest when the newsprint mills compete with the kraft mills for raw material? The production of newsprint paper far exceeds that of kraft. The capital required to build and equip a paper mill runs from seven to ten million dollars or more, and it does not pay to invest that amount unless a long life can be assured to the enterprise. Dr. Herty has been quoted as saying that a tract of 45,000 acres will supply enough wood perpetually for a mill of 150 tons daily capacity. (Many of the new kraft mills have a daily capacity of 300 tons.) But that could only be done on a tract that was organized and systematically developed for continuous production under intensive forest management. It would not pay to reproduce such stands as composed the bulk of the pine barrens even before the lumbermen cut them over, nor would such stands maintain a paper industry for any great length of time.

WINDTHROWN LONGLEAF PINE TREE
DUE TO BOXING FOR TURPENTINE FOLLOWED BY FIRE. WESTERN FLORIDA.

YELLOW PINE REPRODUCTION
THIRTY YEARS OLD, ON AN ABANDONED OLD FIELD NEAR MILTON, FLORIDA. SOME DAMAGE FROM EARLIER FIRES. STAND TOO DENSE AND IN NEED OF THINNING.

But to revert to the grazing business, which has always been important in the South and has good prospects of becoming more important in the future if properly developed. The opening paragraphs of this article suggested the age-long conflict between the stockman and the forester, a conflict that was being waged in the Old World for centuries before America was discovered. The cool, moist climate of Scotland indicates that it would naturally be a forested country, and the Scottish highlands were originally covered with dense forests. But through centuries of sheep-grazing the forests were gradually destroyed and for several hundred years those hills have been covered with grass and heather. Sheep are more destructive to the forest than cattle, but continual burning and grazing will bring our Southern pine forests to a similar fate. The longleaf-pine forest is not so much the forest that fire made as it is the forest that fire made *poor*, and is making poorer from decade to decade when considered as timber-producing property. The director of the recent forest survey states in his report: "An examination of the second-growth forests throughout the belt in both pine and hardwoods shows that much of the area is less than half stocked. Besides being poorly stocked, many of our young forests are filled with cull trees, trees of stunted growth, and trees that are of poor quality and low value for industrial use. . . . The greatest proportion of clear-cut and non-restocked area is found in the naval-stores belt where, in some localities, the long-continued practice of systematic woods-burning has prevented the re-stocking of cut-over land or brought about a worthless cover of scrub oak."

The European forester hates to see

THE RESULT OF PROTECTION AGAINST FIRES IN SOUTH GEORGIA

TO THE LEFT OF THE FIRE LINE, A DENSE POLE STAND OF SLASH PINE. TO THE RIGHT, FREQUENTLY BURNED-OVER, SPARSE, STUNTED PINE SAPLINGS AND TANGLES OF SEDGE GRASS.

BUCKING A TREE UP INTO SAWLOGS
THESE LARGE TREES YIELD CLEAR LOGS AND HIGH-GRADE LUMBER.

A FINE STAND OF LONGLEAF PINE
ENTIRELY KILLED BY ONE BAD FIRE. NORTHEASTERN FLORIDA.

grass on his forest floor as much as a market gardener hates to see weeds in his onion beds. Grass robs the soil of both food and moisture that the trees need for making their best growth, and seriously retards or often prevents reproduction. Because of years of such mistreatment our Southern woodlands are yielding only a small fraction of the timber they are capable of producing if well protected and properly managed. Neither is the use of fire necessary in order to regenerate the forest to pine. The forester knows how to reproduce stands of pure pine or any other desirable species without resorting to fire.

But, on the other hand, the foresters should concede that in trying to convince the stockmen of the evils of woods burning they started off on the wrong track. It is bad for the trees but good for the grass. Since writing his article on the forest that fire made, Mr. Greene has released from time to time further statements[3] concerning the results of his researches, which may be briefly summarized as follows: Cattle gained 45 per cent. more when grazed on areas that had been burned than on unburned areas. The growth of grass was more

[3] The latest publication bearing on this subject is Technical Bulletin No. 683 of the U. S. Department of Agriculture, published in June, 1939, entitled "Effects of Fire and Cattle Grazing on Longleaf Pine Lands as Studied at McNeill, Mississippi," by W. G. Wahlenberg, of the Forest Service, S. W. Greene, of the Bureau of Animal Industry, and H. R. Reed, of the Bureau of Plant Industry. This is a 52-page bulletin describing in detail the experiment that was conducted at the Mississippi Agricultural Experiment Station for ten years, from 1923 to 1933, on four sample areas representing, respectively, burned pasture, unburned pasture, burned ungrazed and unburned ungrazed land. The results of this elaborate investigation may be briefly summarized in the statement that annual burning improves the grazing but is detrimental to the regeneration of the pine. Which simply corroborates the consensus of opinion long held by intelligent observers throughout the Southern pine region.

OPEN GROWTH TURPENTINE ORCHARD IN LONGLEAF PINE VIRGIN FOREST ON CHOCTAWHATCHEE NATIONAL FOREST, FLORIDA. FIRST YEAR OF CUPPING. NOTE LOW POSITION OF CUPS AND NARROW STREAKS.

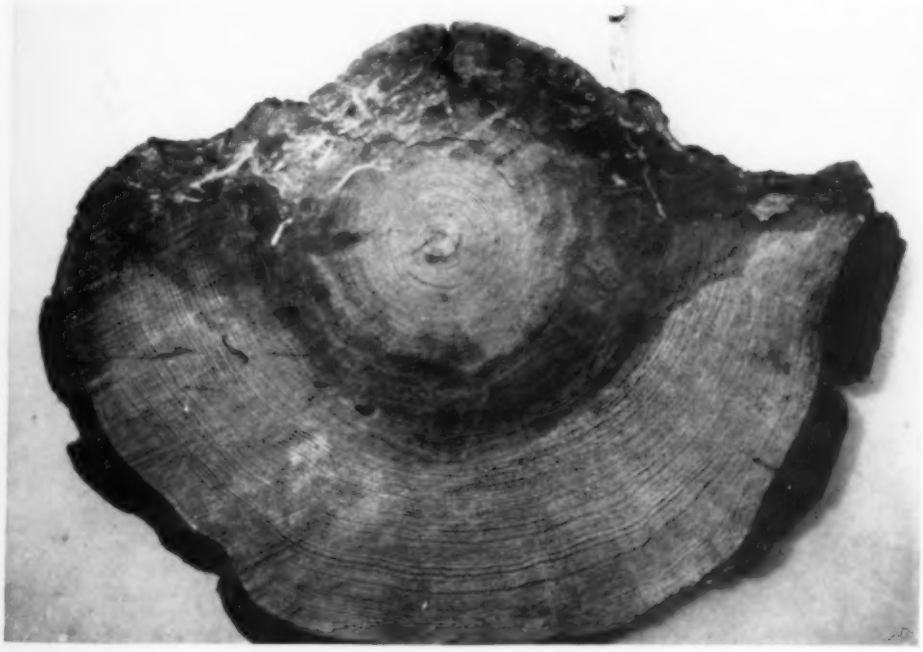
than twice as heavy on the burned than on the unburned area, and there were nearly three times as many legume plants on the burned area. Analysis of the forage also showed that the grasses from the burned areas were much higher in feeding values.

When the foresters came South and appraised, as they did very quickly, the enormous damage to growing timber that was done by woods-burning, they tried to convert the stockmen from that practice by preaching to them that these ground fires were detrimental to the grazing as well as to the timber. They never met with much success in converting the men whose interests were solely in cattle, and now the practice of the live-stock men is confirmed by expert authority. It is a necessary practice in a humid region with naturally dense forest growth if live stock are to be grazed in the woods. The forest must simply be converted into wooded pasture land. With landowners, however, who were more interested in raising timber than cattle, whether for naval stores, saw-timber or pulpwood, the foresters were more successful, and only a few years of protection were enough to convince these people that fire-suppression on their lands was a good thing for them.

Woodlands make poor pastures, and the grazing of woodlands will result in poor crops of timber. Even if not subjected to annual burning a heavily grazed tract of timber will rapidly deteriorate. Pasturing and timber production can not be practised on the same land except to their mutual disadvantage. The conclusion is evident. The production of timber for commercial purposes and the raising of live stock should be conducted on separate areas. In many parts of the South that goal can not be reached in a year or a decade, but

it is the goal toward which we should persistently work. And the change will be greatly accelerated through the pressure exerted by the pulp mills in their efforts to acquire large tracts of land on which to grow their pulpwood. Whether the land be owned by the pulp company or by others who will make a business of growing pulpwood as a crop and selling it to the mills, the signs are plain that enormous areas in the Southern pine belt will be devoted to that purpose in the near future. That will call for good silvicultural practice on all such lands in order to assure satisfactory yields, and that will mean not only the suppression of forest fires but the total exclusion of grazing.

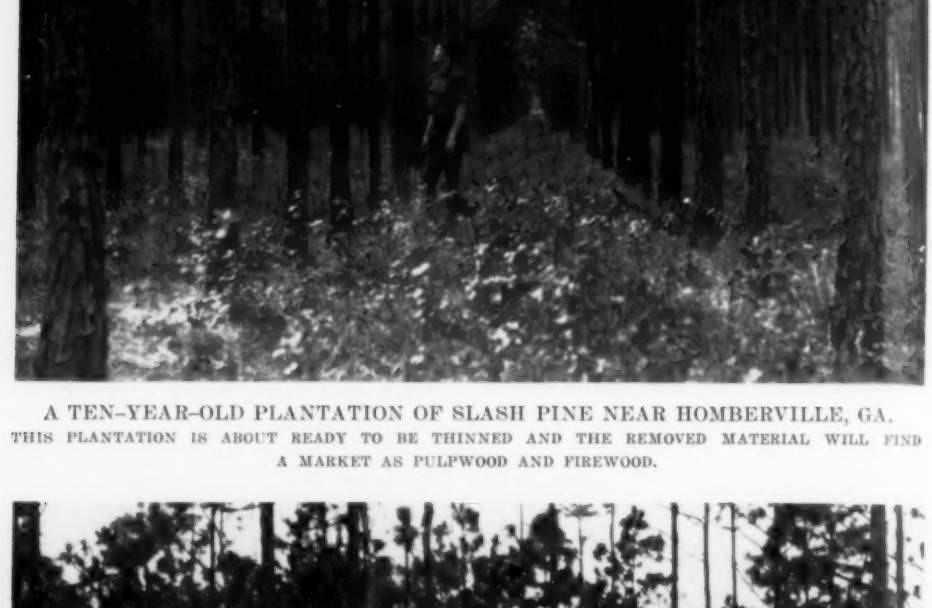
There is another forest industry in this region that utilizes large amounts of land—the time-honored "naval stores" industry, now centered in southern Georgia and Florida. In these two states and the southern part of South Carolina about 90 per cent. of the valuable naval stores (principally turpentine and rosin) are produced. It has been estimated that in this region 75 or 80 per cent. of the pine forests are controlled by men engaged in naval stores production. And it is in this naval stores area that a number of large pulp mills have recently been built. The pulp people have been getting some wood from the turpentine men in the form of worked-out trees, but they will find that they can not depend on this source for very much raw material. For a turpentine *orchard*—as such a property is usually called—is exactly what that name implies, it is more of an orchard than a forest and is as ill-conditioned to produce large and continuous crops of either saw-timber or pulpwood as a



CROSS SECTION OF BUTT OF FIRE-DAMAGED YELLOW PINE

NOTE SCARS FROM ALL FIRES AND SIGNS OF GRUB DAMAGE AND ROT, BOTH AFTER-EFFECTS OF FIRE. HALF THE CROSS-SECTIONAL AREA OF THE LOG IS WASTED.

A TEN-YEAR-OLD PLANTATION OF SLASH PINE NEAR HOMBERVILLE, GA.
THIS PLANTATION IS ABOUT READY TO BE THINNED AND THE REMOVED MATERIAL WILL FIND A MARKET AS PULPWOOD AND FIREWOOD.



OLD FIELD STAND OF LONGLEAF IN SOUTHEAST GEORGIA
A THINNING HAS BEEN MADE, REMOVING MATERIAL LARGE ENOUGH FOR PULPWOOD. THE REMAINING TREES WILL PUT ON INCREASED GROWTH.

heavily grazed woodland. To get maximum production of naval stores requires an open, orchard-like stand of trees with full crowns. It requires twenty to twenty-five years for the slash and longleaf pine to reach a profitable size for turpentining. From then on, by using the most improved methods, the trees may be profitably worked for twenty-five or thirty years. But a crop of pulpwood can be grown and harvested every twenty or twenty-five years. The pulp mills will find that they must grow their own timber or obtain it from people who make a business of growing it for them.

But there is plenty of land in the South for all the timber that could be profitably grown and all the live stock that could be profitably raised. With the cattle tick eradicated the natural conditions are highly favorable for the development of a flourishing live-stock industry. Moreover, pioneer days have passed and we are entering a new era in agriculture. We know that it does not pay to raise the kind of stock that is usually found grazing in the piney woods. Over a hundred years ago it was recognized by competent judges of live stock that the cattle which were brought up in our Southern woodlands were the scrubbiest of scrub stock, as most of them are to-day. In 1815 William Johnson, of South Carolina, a justice of the United States Supreme Court, in addressing an agricultural society in Charleston, spoke of the range cattle "that ordinarily disgrace our cowpens." To-day beef cattle of the pine lands are worth only one third as much as corn-belt cattle. And as for dairy cows, a present-day Carolinian who was brought up among the pine woods stock recently remarked to the writer: "At the best we'd get about a gill of blue milk a day from each critter."

The plain fact is that ranging stock over forest land is a backwoods method, which may have been justified under pioneer conditions but can be justified

COMPLETE DEVASTATION

IN THE YELLOW PINE BELT OF CENTRAL LOUISIANA AFTER DESTRUCTIVE LUMBERING FOLLOWED BY FIRES. NO SEED TREES REMAIN; THE LAND WILL LIE BARREN UNTIL ARTIFICIALLY REFORESTED. TYPICAL OF HUNDREDS OF THOUSANDS OF ACRES IN THE COASTAL PLAIN.

A FIRE-KILLED POLE STAND

OF SHORTLEAF PINE IN ARKANSAS.

TYPICAL SOUTH GEORGIA POLE STAND
WHICH HAS BEEN PROTECTED FROM FIRE.

AN OPEN VIRGIN STAND OF LONGLEAF
ON THE CHOCTAWHATCHEE NATIONAL FOREST.

no longer. Successful live-stock raising to-day can be accomplished only by grazing the stock in permanent open pastures and by growing forage crops. The county agricultural agents in every Southern state are advocating permanent improved pastures, and the most progressive farmers and cattle men are providing them. Not only is the actual amount of forage much less in woodlands than in open pastures, but the feeding value of forage plants grown under forest shade is much less than if grown in full sunlight. It is commonly estimated that a good open pasture will support ten times as many head of cattle as the same area of woodland pasture, but the ratio will depend largely on the density of the woods. The more open the stand the more abundant will be the growth of grass, but the yield of timber will be proportionally less and the quality poorer. A well-managed forest in a humid country like the South will not support any grazing, for there will be no grass.

It is true that live stock are benefited by some shade in hot weather. This should be provided by single trees scattered here and there over the pasture, and by grove-like strips of trees along streams. Such tree-growth should be regarded as permanent pasture "fixtures" and never cut for timber.

The practice of forestry means the raising of timber in successive crops, and if our Southern woodlands be adequately protected from fire and properly handled, timber will be one of the South's most important and profitable crops. It will provide the permanent basis for large lumbering, paper and naval stores industries. But a goodly portion of this region should also be in permanent pastures, raising large herds of both beef and dairy cattle. The future prosperity of the rural South depends very largely upon the wise development of both these resources. There is plenty of land on which to develop both the South's magnificent forest resources and a splendid live-stock industry without mixing the two on the same areas to their mutual detriment.

SCIENCE PROGRESS THROUGH PUBLICITY

By AUSTIN H. CLARK

SMITHSONIAN INSTITUTION

SINCE the beginning of the present century scientific advance has been greater than in all the hundreds of years preceding—or at least since the discovery of fire and the first fashioning of tools. This advance of scientific knowledge is bringing with it certain elements of danger, for the further we advance in any scientific line the fewer are those able to follow the increasing multiplicity of detail and to understand the increasingly complex principles involved. Research workers are therefore running the risk of becoming isolated from the general mass of the population in our social order.

This risk is real. For unless any given group within a social unit is recognized as contributing to the material or spiritual welfare of that unit, sooner or later it will be in danger of elimination. The history of science in England before the Restoration and its development after the accession of Charles II, and the very varying status of scientific research in the different countries of the world today, show us that scientific advance, at least in certain lines, is conditioned by the attitude toward it on the part of the general mass of the population as reflected by their chosen representatives.

We also learn from history that a liberal attitude toward science may at any time change to a more or less restrictive or suppressive attitude. This has happened in recent years in various sections of the United States as well as elsewhere.

We live in a democracy. In a healthy democracy all groups within the population must do their share toward furthering the common good of all, in accordance with their special and diverse abilities. Each group must win and hold the confidence and respect of all the other groups. If science is to prosper and to advance, the population as a whole must take an interest in and appreciate the work done by our scientific men and women. The people must see in scientific work something of value to themselves. They must envision science as continually leading the way to better things—to an easier, safer, more satisfying existence.

Popular interest in science is twofold. In the first place, there is the purely material interest based upon the advantages to be gained in increased comforts, and in increased opportunities for broader social and other contacts, such as, for instance, those afforded by the automobile and by the radio. To these we may add the potentiality for economic betterment, and the increase in personal welfare and security resulting from advances in our knowledge of the several branches of science that collectively make up medicine.

In the second place, there is the interest that is wholly non-material. To every one it is a source of satisfaction to know that we are pushing ever forward into the realm of the unknown the boundaries of our knowledge. And as we do this, we are at the same time opening up new vistas of the unknown, beyond which we sense the vast realm of the unknowable.

We can never know everything. The more we learn, the more clearly do we appreciate the infinite extent of that which we can never know. Instead of gradually confining the human mind between barriers of facts and formulae, science leads us on to a more satisfying contemplation of the infinite.

Only a few years ago this broadening

of the intellectual horizon was confined to those actively engaged in science, or closely associated with the students of science. And these alone appreciated the potentialities of scientific advance in its social and economic aspects. But now this knowledge is being broadcast to all our people so that every one may understand and every one may benefit.

This exposition of the advance of science is being carried out as a cooperative enterprise. Increasing numbers of our scientific men and women are willing to let others know what they are doing. By the members of the National Association of Science Writers their work is accurately interpreted and expressed in popular language that all may understand. Because of their importance to the general public, the accounts written by the science writers are laid before the public by the editors of our newspapers and our magazines.

This cooperation between the research workers, the science writers and the editors has proved of great benefit not only to the people, but to science itself. Frequently it has happened that a story written by one or more science writers has stimulated such general interest in a subject that a flood of additional information became almost immediately available, or further investigation was greatly facilitated as a result of popular demand. Without such an awakening of public interest it would have taken many years to have acquired the knowledge that we have to-day.

Out of the many cases available I shall take two that have occurred within the past few years, one showing how the diffusion of knowledge through the press

FOUR OF THE FIVE PULITZER PRIZE WINNERS

IN THE NATIONAL ASSOCIATION OF SCIENCE WRITERS; AT THE TABLE, LEFT TO RIGHT, MR. JOHN J. O'NEILL, SCIENCE EDITOR, *New York Herald Tribune;* MR. DAVID DIETZ, SCIENCE EDITOR, SCRIPPS-HOWARD NEWSPAPERS; MR. WILLIAM L. LAURENCE, SCIENCE NEWS EDITOR, *New York Times;* SEATED, BETWEEN MESSRS. O'NEILL AND DIETZ, MR. HOWARD W. BLAKESLEE, SCIENCE EDITOR, ASSOCIATED PRESS; MR. GOBIND BEHARI LAL, SCIENCE EDITOR, INTERNATIONAL NEWS SERVICE, IS NOT SHOWN. OTHERS IN THE PICTURE ARE MR. WATSON DAVIS, DIRECTOR, SCIENCE SERVICE, EXTREME LEFT; AND DR. SIDNEY S. NEGUS, MEDICAL COLLEGE OF VIRGINIA, EXTREME RIGHT.

has helped pure science, the other showing its effect on applied science.

In 1926 there was discovered at Folsom, New Mexico, in association with the bones of an extinct bison, an arrow-point of a type quite different from the usual Indian projectile point. In 1928 this discovery received much publicity in our press. In the spring of 1934 one of these so-called Folsom points was discovered near Richmond, Virginia. This find, announced in the press by the science writers, attracted immediate attention all over the country, with the result that many notices of the discovery of similar points were received at the Smithsonian Institution.

From these notices, verified by the specimens submitted, it was learned that arrow-points of this type are pretty widely distributed over the country, though chiefly east of the Rocky Mountains, and furthermore an extensive camping place of Folsom man—the now famous Lindenmeier site—was located in northern Colorado and brought to the attention of the Smithsonian Institution.

Thus our present knowledge of the interesting and unique Folsom culture, the earliest human culture in North America of which we have any evidence, has been pieced together almost entirely from facts brought to light primarily as a result of the work of the National Association of Science Writers.

Pure science is profiting more and more through the cooperation of the research workers, the science writers and the editors. The benefits of this cooperation have been even more marked in applied science. Let us take an example from the field of medicine. There is nothing that appeals to us more strongly than the alleviation of human suffering, and it is in this field that the science writers have done some of their most outstanding work.

Long ago it was noticed on battlegrounds that wounds infected with the larvae of blow-flies healed more readily than uninfected wounds. But this knowledge was not put to practical use until about a decade ago. In 1929 Dr. W. S. Baer published in the *Southern Medical Journal* a description of a new and unusual treatment for slow-healing wounds, such as the persistent and wide-spread bone disease known as osteomyelitis. The treatment consisted in placing sterile blow-fly larvae directly in the wounds that had failed to heal under other treatment. After a few applications of the larvae the wounds in general became cleaner, and healing began to take place.

Investigations were undertaken to determine the substance or substances in the secretions of these larvae responsible for the beneficial effect. One of the substances was found to be allantoin, easily produced synthetically.

In 1935 Dr. William Robinson published an account of healing in non-healing wounds resulting from the application of allantoin. This was at once given wide publicity by the science writers, and accounts of Dr. Robinson's work appeared in newspapers and other journals at intervals throughout the following year.

As a consequence of these accounts, a large number of physicians and surgeons obtained allantoin and used it clinically, and many inquiries were received from people who wished to treat themselves; furthermore, a number of chemical and pharmaceutical companies undertook the manufacture of synthetic allantoin, and of various preparations containing it.

This is an excellent example of how the science writers have aided in bringing into general use within a very short time a valuable curative agent.

The importance of the work of the science writers in this connection is emphasized by the fact that the use of allantoin had been suggested long ago. In 1912, before the inception of modern science reporting, Dr. C. J. Macalister in

an article in the *British Medical Journal* had reported the successful use of allantoin in the treatment of chronic ulcers. But his work attracted little attention at the time and was soon forgotten.

In August, 1936, attention was called to the remarkable healing properties of urea, another substance present in the excretions of blow-fly larvae. The science writers gave this discovery also extensive publicity, and urea is now receiving wide attention by the medical profession, with very encouraging results.

In the history of modern science writing there are many cases such as these. Science and the press are now united in a partnership that is becoming closer every year.

To every one interested in the advance of science it is a source of the greatest satisfaction to note that tangible recognition of the importance and value of the work of the members of the National Association of Science Writers is increasing. Honorary degrees and memberships in scientific societies and scientific clubs are being conferred upon them. No less than five of them have received the Pulitzer Prize for the excellence of their work. A few months ago the association as a whole was honored by the award of the Clement Cleveland medal for outstanding work during the preceding year in the campaign to control cancer. It may be of interest to add that many of our research workers, as well as interested laymen, are now with complete confidence keeping themselves in touch with scientific advances in lines other than their own by reading the notices in the daily press.

Now it is self-evident that the increasing success of the science writers in presenting science to the American people in accurate and readable form has been made possible by the increasingly sympathetic attitude of the enlightened editors of our newspapers and magazines, who see more and more clearly that science, accurately displayed in their pages, is not only of interest but also of value to the public.

With our corps of able science writers and our intelligent and appreciative editors we may hopefully look forward to the future, provided we who are engaged in scientific research do our part. We must continually bear in mind that we are an integral part of the society in which we live, not a select or selected group, and that others are quite properly interested in what we do, just as we are interested in what our fellow citizens are doing.

But in connection with our scientific work we speak a dialect incomprehensible to most of the other elements of the community, and our method of thought is along channels with which the average man is almost wholly unfamiliar. So we need interpreters. These interpreters we have in our science writers who understand our language and also the language and the mental attitude of the general public, with which we are more or less unfamiliar.

Our duty to the community in which we live, to science, and to ourselves, is to take the public completely into our confidence and to provide the interpreters —the science writers—with all the material they can use. In bringing science to the people we have already made enormous progress. The groundwork is now complete; but much still remains to be done to perfect the superstructure.

OCEAN PASTURAGE IN CALIFORNIA WATERS[1]

By W. E. ALLEN

SCRIPPS INSTITUTION OF OCEANOGRAPHY OF THE UNIVERSITY OF CALIFORNIA

For ages, seafaring men have had their interest stirred, at certain times and places by conspicuous conditions of the sea due to the presence of microscopic plants (phytoplankton). Most often, their attention has been attracted by very distinct discolorations ("red water," "brown water," "yellow water," etc.), although the odor of sea water has been strongly prominent also sometimes ("stinking water"). In addition, there have been times and places when fishermen have had trouble in handling their nets or gear because of coatings of slimy material consisting of microscopic plants. Such experiences alone are sufficient to raise questions concerning the causes and relationships of the observed conditions.

In more recent years, because of increasing attention to details of ocean characteristics, less conspicuous occurrences and displays of phytoplankton phenomena have led to comprehensive studies of the microscopic plants and their activities. From such studies it has come to be understood that phytoplankton distribution in seasons (or other periods), in depths, in localities and in latitudes has direct relationships to movements of air and water masses (regular and irregular, systemic and turbulent), and that it both influences and is influenced by turbidity, density, temperature, light, dissolved substances, co-existent organisms and indefinite numbers of other chemical, physical and biological characteristics of sea water. In particular it is generally recognized to-day that phytoplankton constitutes the basic food supply (ocean pasturage) which directly or indirectly furnishes sustenance for commercial fishes and other animals at the same time that it draws much of its own sustenance from them. Not only so, but phytoplankton furnishes much of the food used by sedentary animals useful for human food (oysters, etc.) or harmful to human enterprise ("fouling organisms" so injurious to ship bottoms and other structures exposed to attack).

As recently as 1919 practically nothing was known concerning phytoplankton in the Pacific Ocean. Indeed, an authoritative paper published in Philadelphia as late as 1927 commented on the small numbers of kinds of diatoms and their thinness of population in the Pacific, although local investigations were already showing the contrary fact for this most important contributing group. Because of the necessity of knowing names and identities when discussing or investigating the relationships of any natural object or group of objects to conditions in the sea much time had to be given to mere identification and naming of specimens in the first few years of researches at the Scripps Institution of Oceanography at La Jolla, California. Thereby it was found that although more than two hundred species of phytoplankton organisms live in the East Pacific, less than fifty species ever become so abundant as to attract special attention, even from specialists. Although diatoms are distinctly most important in most years in most localities, the group of dinoflagellates sometimes takes a temporary lead in production of ocean pasturage.

Fortunately, while learning identities, it was possible to accumulate other

[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 122.

kinds of data concerning the components of phytoplankton. The records showed that no single species was ever able to hold the lead in production over a long period of time, rarely longer than ten days. Also it appeared that production tended to be best before July, although there might be a difference of a week or two in this tendency at two stations only a little more than one hundred miles apart. Twenty years of investigations have revealed that no two years were alike at either of two stations and that two years of unusually warm water (1926 and 1931) were poorly productive of both diatoms and dinoflagellates at both stations.

About three thousand catches by boat at offshore stations have shown that phytoplankton may reach notable abundance more than one hundred miles from shore and at depths as great as seventy meters, large numbers, however, rarely being taken below fifty meters. Sometimes many diatoms appear at lower levels though few at the surface, sometimes many appear at the surface when numbers are small below, and sometimes rather large numbers may be found at all seven of the levels sampled at a particular station. Unexpectedly, large numbers in good condition are taken sometimes from levels below large numbers in poor condition. As a matter of fact, no large numbers of specimens in dead or decadent condition have been observed below any dense population in vigorous condition, although one might suppose that many would die and sink.

A notable difference of abundance of phytoplankton between two stations indicates a difference between them in respect to chemical composition of the water, physical constitution of water masses, behavior of water masses, climate or meteorological conditions, or animal populations. If such a difference in phytoplankton populations does no more than prevent hasty or rigid conclusions and inferences from being asserted on the basis of close similarity of too few chemical or physical observations, it is worth something. When it confirms the validity of an observation of an unexpected difference in those conditions it becomes distinctly helpful. That is to say, microscopic plants naturally detect and respond to chemical and physical conditions of their environment which are too delicate for one to detect by routine methods in a laboratory. Therefore, proper attention to their responses to unnoted changes in those conditions may lead to correct interpretations or to changes in routine which lead to better if not to full understanding.

In some localities most of the oxygen in sea water is derived from the air. In other localities (or at certain periods) most of it is derived from phytoplankton. In the one case no immediate effect on the chemical composition of sea water is necessarily involved in the processes of introduction.

In the other case, incident and immediate changes occur in substances containing carbon, sometimes involving indefinite series of chemical changes in surrounding sea water. So far, no one has ever evaluated the contribution of oxygen by phytoplankton in the ocean although chemists, physicists and biologists are agreed that in the matter of oxygen transfer alone the microscopic plants hold a prominent place in the network of environmental influences. Although the twenty years of phytoplankton research have shown conclusively that periodicity of production and occurrence is not predictable for any restricted or specific place or depth level, they have shown that cloudlike aggregations of diatoms and dinoflagellates run a course of increase and development during which much might be learned about the influences of phytoplankton through oxygen production

(and consumption). While the requirements of trustworthy investigations of this problem under natural conditions may be too expensive at present, it is none the less true that the opportunity exists.

Similar statements may be made concerning investigations of occurrence and distribution of carbon, phosphorus, nitrogen and their compounds as well as other elements and substances not mentioned so frequently. Although many people seem to feel confident that relationships of influences of temperature may be easily detected, described, and evaluated, it is more probable that a clear understanding of any but the grossest manifestations of temperature conditions is very difficult to obtain. Still, there is no doubt of the fact that adequate phytoplankton data may aid substantially in understanding coincidental phenomena of temperature. Probabilities seem to be even better for such influences as viscosity, density and light.

Repeated cruises continue to show that phytoplankton abundance has a recognizable relationship to turbulence, upwelling, oceanic drift and to major and minor currents. It is entirely reasonable to expect that understanding of these relationships will improve rapidly as more data of the same kind as those yielding these results are accumulated.

So far, inshore and offshore conditions are not clearly understood as to manner and degree of influence but much is apparent already in fact. For example, certain species which reach abundance offshore are rarely noticeable inshore (and *vice versa*). Also, certain localities near shore appear to be more productive at certain periods or seasons while certain localities offshore appear to be more productive at other periods or seasons. Here there can be no question that familiarity with phytoplankton populations in their native habitats will help to clarify these relationships either when time and effort can be spared for them directly or as data accumulate otherwise. Possibly even better progress can be made toward understanding of characteristics of deeps and shallows by giving careful attention to phytoplankton relationships in or about them.

Practically nothing is known concerning the more direct effects of run-off from land, not to mention the indirect effects. Even Gran appears to have rejected an earlier opinion that run-off enriched sea water, but it is surely reasonable to suppose that this enrichment ensues, nevertheless. Whatever the facts may be, it seems certain that the phytoplankton must be depended upon for evidence leading to a final solution. Doubtless this solution will be delayed a long time because of cost of specific researches required by it, but the phytoplankton data accumulated by the Scripps Institution affords a sound foundation upon which to base the necessary investigations, not only of the nutrient influences of run-off but also of dilution and sedimentation influences.

To geologists (especially petroleum geologists) plankton diatoms are highly interesting because of their relationship to problems of oil-producing sediments. If one can learn why diatom frustules are deposited here and not there, and why sometimes no diatom deposits can be found at or near localities which are known to yield them abundantly, he may be able to account for some of the vagaries of deposition. Some of the observed conditions of occurrence suggest the probability that many diatom frustules dissolve during long support or transport without sinking to the bottom, thus maintaining in the water a fair supply of siliceous material to be used by their own kin.

So far Scripps Institution work on phytoplankton has contributed nothing to direct knowledge concerning the con-

tinuous series of changes of organic wastes in the sea. We know that the little plants must use other things besides carbon dioxide, but we do not know what forms of the various substances are most valuable in their activities, nor how they meet fluctuations in amounts of preferred materials. However, the records of occurrence of phytoplankton bring necessary information to the point where intelligent selection of species and localities may be made for conducting observations.

Concerning relationships with other organisms much that has been said above will apply. However, it seems probable that phytoplankton data are even more important for any one who undertakes to identify and trace food chains (*e.g.* diatoms, copepod, sardine, mackerel, squid; or diatom copepod, hydroid) involving either free-living or sedentary animals. Still, the food relationship is not the only one. For example, researches indicate that phytoplankton may become so abundant sometimes as to seriously injure many surrounding animals, possibly by mere crowding, possibly by clogging of the gills, possibly by direct poisoning in some cases.

CENTRALIZED EDUCATION

I HAVE no hesitation in saying that the complete domination of education by the state in Germany was what made it so easy, when her war lords had decided to embark upon a career of world conquest, to obtain the aid of her university professors, philosophers, and historians alike, though not all of them, in spreading *der tag* psychology throughout the whole of her population. I myself saw this happening in the nineties in Germany, and in 1907 I heard the man they called their greatest historian, Edouard Meyer, before 2,600 students in Mandel Hall glory in war and conquest as the finest developer of a people. *That was what made the Great War.*

Today it is very much worse because the centralization and control of the educational system enables the gangsters who have seized control of government to use the whole machinery of education, including the press and the movie as well as the schools, for *indoctrination*, instead of education, for substituting for the free growth of knowledge the rank growth of ignorance of every fact or idea which could militate in any way against the interests of the gangsters and the continuation of their power. It was because Spinoza saw the inevitability of this result of a centralized educational system that he opposed completely the placing of education in the hands of the state.—*Address by Dr. Robert A. Millikan, California Institute of Technology at Pasadena.*

THE ORIGIN OF OUR NUMERALS

By JOHN DAVIS BUDDHUE

PASADENA, CALIFORNIA

We are accustomed to use two kinds of numerals with very different histories, the Roman and the so-called Arabic numerals. It is probable that neither of these names is the correct one, for the Roman numerals appear to be of Etruscan origin, with perhaps a trace of Greek, while the Arabic figures are really of Indian origin.

To begin with the Roman numerals, the first three are obviously a representation of a numerical idea by making an appropriate number of lines. Four is for some reason written as 5 – 1. The use of V for five is said by some to be a symbol of the hand held up, one arm representing the thumb and the other, the fingers bunched together. According to this line of thought, X is simply two V's, one of them inverted. Similarly, C is an abbreviation of *centum* = 100, and M is *mille* = 1000. Unfortunately, this system does not account for D = 500 and L = 50, since neither of these is the proper initial letter. Consequently we must look for something better as an explanation.

According to the Etruscan system of numeration, 100 was represented by a circle divided into quadrants. By removing the circle X was left and used to represent ten. Proceeding along these lines, V was obtained by dividing the X in half, exactly the reverse of the above incorrect system of derivation.

For 1000, the Etruscans used a circle with a vertical line dividing it. This was also adopted by the Romans. Half of the circle gave D, or 500, and another kind of division gave an inverted T which was eventually changed into L, or 50, because it could be written with one continuous line. As for M, we must leave the Romans and Etruscans and examine some samples of old printing. For some reason, no one seems to have thought to cast type for the Etruscan symbol of 1000 and a makeshift was used thus: CIↃ. This was rather cumbersome and was largely abandoned in favor of M which bore more or less resemblance to the true sign and also was the initial letter of *mille*. C was originally a circle, but that was liable to cause confusion with the letter O; therefore, C was put in its place because it was the initial of *centum*.

The Roman numerals therefore are hardly alphabetic although the suggestion has been made that the signs for 10, 50 and 100 were derived from the Greek letters Χ, Ψ and Φ, respectively.

The Indo-Arabic numerals have had a much more extensive history and few people would recognize them in most of their earlier forms. Their ultimate origin is unknown but some trace them back to the Egyptian Heiratic and therefore to the Heiroglyphic. A better suggestion is certain letters of the Indo-Bactrian alphabet. It will be noticed that the phonetic values of these letters are given. This is to call attention to the fact that they are really initial letters for the number words in Zend or Sanskrit or both. Thus 4 = chathwar (Z), 5 = panchan (Z), 6 = shash (S), 7 = saptan (S), 8 = ashtan (S), 9 = navan (S, Z) and 10 = dasan (S, Z). Consequently it would seem that those old Aryans began to write numbers by drawing a series of short lines just as the ancient Romans and Egyptians did, but they soon got tired of that cumbersome method and decided to use the initial letters of their number words instead. That at least was an improvement over the Greek and Semitic system of using letters for numbers

that bore no relation to the sounds of the number words.

Whatever their origin, the earliest known use of the prototypes of our numerals are found in the Nana Ghat inscription of India. Later came the Cave inscriptions which were made some time early in the Christian era.

It is important to note that positional notation was unknown until, probably, some time in the sixth century A.D. That is, there was no zero, and ten, eleven, etc., were written with separate symbols. But eventually some unknown mathematical genius invented a zero and the positional system was born. The invention of zero was probably a result of the abacus or a similar device such as a smooth board covered with sand. The number 204 would be written by making three columns. In the first two lines would be made, the second would be left blank and four lines would be made in the last column. No doubt it occurred to this unknown mathematician that the same result could be accomplished by using numerals, provided that there were a symbol to denote the empty column. Thus zero was born and named *sunya* (empty, blank).

At any rate, the numerals together with zero were adopted by the Arabs. They probably learned them from some mathematical tables brought to Bagdad by an Indian ambassador in 773 A.D. From there the knowledge of them spread slowly over the whole Arabian world. There were two principal variations of these numerals, the Eastern and the Western or Gobar. The latter word means dust and suggests that some sort of sand abacus was known. This variant was used in Spain by the Moors and in Africa. It is the prototype from which our numerals were derived and the resemblance to our modern numerals is by now quite clear.

At the time of the introduction of the numerals into Europe a modified abacus was used in which numerals replaced the counters but zero was represented by an empty column again. This was used at Rheims about 970–980 by Gerbert, who later became Pope Sylvester II, and by the eleventh century it was well known. There is no direct evidence to show where Gerbert learned of it. According to William of Malmesbury he stole it from a Spanish Arab, but this theory is usually regarded as a mere fable. Still there is no known use of the abacus in Europe at an earlier date except in the *Geometria* attributed to Boëtius. If this book is genuine we have direct evidence that somehow the Indian numerals got into Europe in the fifth century, and Gerbert only resurrected a system forgotten for 400 years, more or less. If this is true, then how did Boëtius learn of it? He himself describes it as the system of the Pythagorici. This suggests that the old Indian numerals along with the abacus was introduced into Alexandria some time before the fourth century A.D. when communication between India and Europe ceased. In fact the close resem-

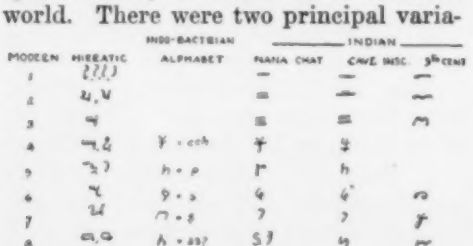


FIG. 1.

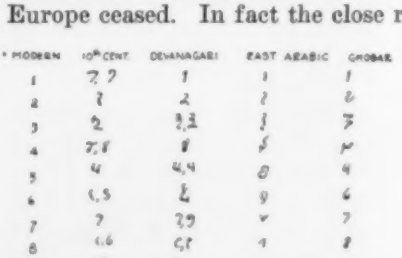


FIG. 2.

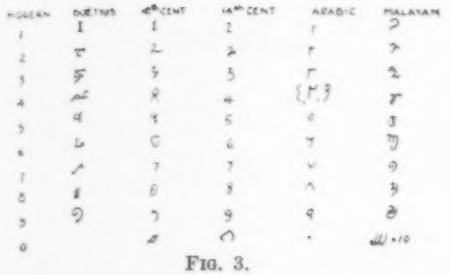


FIG. 3.

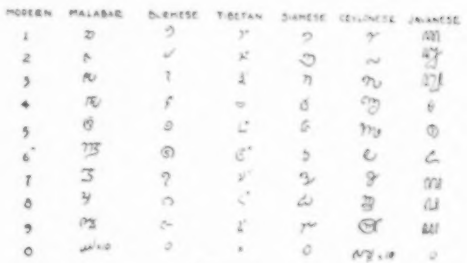


FIG. 4.

blance between Boëtius' figures and the Gobar Arabic has led F. Woepcke to believe that the western Arabs adopted their system from Boëtius before the Indian method with a zero reached them. There are many difficulties to this view however, among which is the difficulty in explaining the rather close resemblance between the Gobar and the Eastern Arabic system if the two had been separated for some hundreds of years. Moreover, the authenticity of the Geometria is not established, and it is quite possible that Gerbert or some one else obtained a partial knowledge of the abacus and the numerals from the Arabs but failed to obtain, or to understand, the idea of zero.

Later on the zero was added and the abacus fell into the discard. Few people know of it now, except as a plaything for children. The word zero is of Arabic origin. When the Arabs obtained the numerals from the Indians they translated the Indian *sunya* into their own word *sifr* with the same meaning. When the numerals were introduced into Italy, *sifr* was Latinized to *zephirum*. This happened some time near the beginning of the thirteenth century. Various changes occurred during the next hundred years ending in the word *zero*.

However when Jordanus Nemarius introduced the Arabic system into Germany he kept the Arabic word but changed it into *cifra*. This word was retained and used as late as the time of Gauss. In English, *cifra* became *cipher* and in other parts of Europe we find *chiffre, ziffer,* etc. However, there was a strong tendency for these words to be taken to mean "numeral" and not "zero." The learned knew perfectly well the true meaning of the word, but the common people did not, and as a result a great deal of confusion arose. In fact, the word even came to signify a secret sign, hence our word *decipher*. At last the confusion was removed by the adoption of the Italian word zero.

It must not be imagined that the transition from the abacus system used by Gerbert to the positional numeration of the present day was easy. It was not. There was a battle raging between the abacists, who defended old tradition, and the algorists, who preferred the newer system, that lasted for 400 years, from the eleventh to the fifteenth centuries. In some places the Arabic numerals were not allowed to be used on official documents or were even prohibited altogether.

The Eastern Arabic numerals had little to do with the development of the sytem we use although they sprang from the same source. They did give rise, however, to the present-day numerals used by the Persians, Turks, Arabs, in fact, any one using the Arabic alphabet. In the figure it will be noted that three forms are used for the numeral four. Of these, the first is used by the Malays, the second by the Arabs and the last by the Persians. Otherwise, they are the same everywhere in the Mohammedan world.

I give also the Sanskrit and other oriental numeral systems, all of which are derived with more or less elaboration from the same source as our own, namely, the old Indian numerals. Some of them still retain a separate sign for ten.

EMERGENT RACES AND CULTURES IN SOUTH AMERICA

By Dr. JOHN GILLIN

ASSISTANT PROFESSOR OF ANTHROPOLOGY, THE OHIO STATE UNIVERSITY

THE tropical lowlands and low plateaus of South America—often referred to collectively as the Tropical Forest Region—constitute about half of the land surface of the southern continent and the largest continuous natural area in the Western Hemisphere. Yet this vast territory is one of the most sparsely inhabited of the globe and one of the least "exploited" in terms of human values, economic or otherwise, either by its natives or by outsiders. Therein seem to lie a group of scientific problems awaiting investigation with which anthropologists are particularly fitted to deal.

Americanists have hitherto been primarily concerned—and legitimately so—with archeological studies, historic reconstructions and ethnographic investigations of the aboriginal racial groups, cultures and languages of this part of the world. It is unlikely that any qualified judge would seriously object either to the aims or to the results of the larger portion of this type of work. And all anthropologists would doubtless agree that, far from being outmoded or completed, investigations of the traditional sort have only begun the great task which must be accomplished if we are to have comprehensive answers to the many questions of aboriginal racial and cultural development which demand explanation in this region.

On the other hand, it would be strange, indeed, if cultural anthropologists, of all people, were unaware of or indifferent to cultural and social developments taking place in the world of contemporary affairs. Recently public interest in many quarters, and particularly that of responsible leaders in the United States, has been increasingly attracted toward South America. We need not analyze nor judge the motivations of these interests here. But the fact is evident that business and financial experts are bestirring themselves over the future of markets, production and the development of resources and trade in South America. Statesmen ostentatiously strive for new modes of political collaboration. Military strategists have evinced a serious concern with the problems of defense and attack of the Americas. Cultural exchange between the various nations of the Western Hemisphere has been, at least formally, increased and placed on a higher plane. Scientists from many disciplines are enlisted to some extent in the formulation and solution of newly significant problems.

Any program of intelligent planning for human adjustment either for the present or for the future must rest upon sound information concerning the physical composition and cultural and social development of the population concerned. In providing information of this kind it seems that anthropology can make a contribution of tremendous significance in South America. It is perhaps not the function of the anthropologist to enter partisan controversies, but he does have the obligation and the techniques to provide a reliable basis of data upon which politicians and business men, for example, may act if they will.

It would not be difficult to document the view that much of the current thinking concerning South America is based

upon lack of realism regarding the actual anthropological situation in the southern continent. Such documentation would consist of the citation of current commonplace utterances which, while widely diffused, smack of the grossest ignorance. Thus in the United States it is not uncommon to speak of Latin American society as resting primarily upon somewhat "debased" Spanish and Portuguese institutions. We tend to think of the nations to the south in terms of an industrialized urban society supported by family homestead farming, which characterizes much of our own country, and to judge them in these terms. Misconceptions of a similar nature are not confined to the United States, but are likewise predominant in many South American capitals and centers of civilization with respect to conditions in the outlying regions. In my own experience I have found in various capitals the foggiest comprehension of realities concerning the interior and the difficulty of finding reliable guides and information is familiar to most travelers into the interior. Thus in 1934, at least, the views of the intelligentsia and government experts of Guayaquil and Qnito concerning the Ecuadorian Oriente could properly be described under the heading of folk tales and mythology. Few even of the permanent residents of Georgetown and the coastal region of British Guiana in 1933 had any more precise notion of the interior of their own country than they had of the interior of New Guinea, with which it is so often confused by ordinarily intelligent persons in the United States. The separatist tendency of the Peruvian montaña, with Iquitos as its center, is notorious and was in large part responsible for the Leticia incident—all largely due to ignorance in Lima concerning the eastern part of the country. As Beals says, "South America for the most part is a peripheral population, a seacoast population. The interior still has to be properly settled and exploited."

Let us consider in more detail the interior and particularly the largest and least known portion of it, the tropical lowlands and low plateaus. It is estimated from data by Zon and Sparhawk in "Forest Resources of the World," that from 40 to 50 per cent. of the continental area of South America is forested, and that by far the greatest portion of this forest cover is of the tropical lowland or jungle type. Southern Chile is the only region of extensive forest outside the tropical zones, and the Chilean forest is comparatively insignificant in terms of square miles. Here we may focus attention primarily on that portion of the jungle area comprised within the drainage of the Orinoco and Amazon, plus the Guianas. The area thus defined (Amazon-Orinoco-Guianas) is far larger than any other in the New World, covering some 3,240,000 square miles, or nearly 46 per cent. of the land area of the continent. Considerable portions of this vast province are only lightly forested, and some of it is plateau country (*e.g.*, southern Guiana, parts of Matto Grosso, etc.), but the major part is typical jungle.

Anthropologists have been primarily concerned with the aboriginal tribes of this area, and while a vast amount of detail remains to be recovered, we must face the fact that the native population is relatively small, probably not more than 300,000 to 500,000 at the most, and that the density of population of all types is considerably less than one per square mile. Furthermore, the Indian population, or a large part of it, has been exposed in varying degrees to contact with Europeans for about 400 years. In spite of this scarcity of population, since the collapse of the rubber boom in the second decade of this century, the tropical lowland area has remained one of the largest blank spaces outside the

polar regions on the face of the globe, not only from the point of view of population density, but also from that of cultural importance in terms of a world system dominated by Western civilization. Nevertheless it is open to doubt that this condition will long continue in a world dominated by expansionist economic systems and containing certain societies seeking "living space." The Belgian Congo, a smaller but environmentally analogous region, supports a population of over ten million with an estimated density of about 12 per square mile, according to the recent comprehensive "An African Survey," edited by Lord Hailey. In view of the fact that the African tropical forest area, while generally similar to that of South America, is if anything a more rigorous environment for human life, it hardly seems that the present relative unimportance of the Amazon-Orinoco-Guiana region is to be explained entirely on the basis of environment, but rather in terms of deficiencies in human stock and culture.

It is generally conceded that the tropical lowland area of South America is a source of considerable potential wealth in raw materials. Yet it receives little attention from social scientists other than ethnologists interested in primitive tribes, and nearly half of South America is thus written off as of small immediate or future importance to human affairs. The justification for this neglect usually follows these lines: (1) Natural resources, while abundant, can not be economically exploited, due to inaccessibility, smallness and lack of organization of the labor force and unprofitable condition of world markets. (2) The standard of living of the inhabitants is too low to permit profitable economic relations with nations of the middle latitudes, other than of the crude exploitative type. (3) Experience has shown that permanent white populations do not prosper in the low wet tropics, apparently in large part at least because of adverse reactions to the climate, so that such areas can not be looked upon as future regions for settlement from Europe or North America.

These arguments seem to me to be predicated on the traditional European imperialist attitude that the low tropics are of value only as reservoirs of raw materials to be exploited by a handful of white masters who use a socially and economically depressed native population as a labor force, primarily under the gang system on plantations or in mines. In such a set-up the whites are maintained in small numbers and temporarily by capital and cultural imports from the mother country. And the natives are persuaded or forced to depend upon home-country manufactured goods. According to this traditional view, therefore, a tropical region which does not contain a large, hardy and amenable native population, together with other conditions necessary for the usual extractive exploitation, is considered of no potential importance. It is not surprising, then, that tropical lowland South America has remained uninteresting to old-fashioned capitalist imperialists.

The possibility has never seriously been considered, so far as I am aware, of the emergence of a blended racial type and of a blended culture capable of developing cultural and economic relations of an independent and mutually profitable character with the nations of the middle latitudes. It is this possibility which I believe anthropologists could investigate with advantage to all.

The dream of large-scale permanent white settlements in the low wet tropics has been dissipated by recent investigations and by several centuries of experience. A. Grenfell Price has most recently summarized the evidence on this matter in "White Settlers in the Trop-

ics," and the 1939 report of the British Guiana Refugee Commission to the Advisory Commission on Political Refugees appointed by the President of the United States concludes that experimental colonization by whites in that colony is feasible, but only in a comparatively dry and non-forested savannah and hill district. Without citing more of the voluminous literature on this subject we may say that the prospects of a pure white society in the low wet tropics of South America appear to be remote. Likewise it is doubtful that a pure Indian society will occupy the region in the future, if for no other reason than that the process of extermination and intermixture with elements of white or negroid ancestry, which has been proceeding inexorably for four centuries, shows no signs of abating. The northeastern region of Brazil is now occupied by a mixed combination of white (Portuguese), negroid and aboriginal Indian elements, the sociological and historical aspects of which have been ably studied by Gilberto Freyre, among others. Says Freyre in his "Casa Grande e Senzala," "The Portuguese triumphed where other Europeans failed. The Portuguese was the first society of modern times constructed in the tropics with national characteristics and qualities of permanence. . . ." These results were, according to Freyre, obtained by devoting first and foremost energy toward the creation of wealth in Brazil itself, rather than to its extraction, and also by the borrowing and recombining of many Indian traits, "making use of the indigene, particularly the woman, not only as an instrument of labor, but also as the basis for the formation of a race of mixed bloods." For other parts of the lowland tropics we also have a sufficient number of scholarly observations of a descriptive, not a metrical type, on race mixture to indicate the general outlines of the process which seems to be taking place.

The first suggested line of research for anthropology, then, would be in the physical anthropology of the race mixtures of the tropical lowland region. Not only do we need information of a scientific, metrical nature concerning the actual somatic types which are emerging from the blending process, but we would also welcome psychological and medical data. Are the new types, like their Indian and Negro forebears, capable of resisting the tropical climate which seems to be so injurious to permanent white occupation, and at the same time have they inherited the "nervous energy" of their white ancestors? In short, is a stable, physically adapted population developing in this region which will be able to grow and to develop a social and cultural life of its own, free from domination of the middle latitudes but capable of carrying on reciprocal relations with the cultural centers of the temperate zones for the mutual benefit of all? There are many indications that such a development is taking place, but only scientific anthropological studies will enable us to grasp its true significance and to estimate its trend in the future.

The problem of *cultural* blending is of equal importance to that of racial blending, and herein lies the second group of problems to which anthropology should be able to contribute. There can be no dodging the fact that the aboriginal cultures of this region will be either modified or absorbed. Every one is familiar with the fact that the Western civilization of the middle latitudes is not easily transplanted to the wet tropics. In those instances where European and American material cultures is existent in the wet tropics, as in the Panama Canal Zone and in the colonial cities of certain western powers, it is well known that it is either extensively modified or it is maintained uneconomically by heavy financial support from the home country. And the "decay," as it is

sometimes called, of Western standards of conduct in the tropics is notorious, and has been extensively described both in fiction and in serious scientific reports. To anthropologists familiar with the general principles of the culture-environment relationship it is unreasonable to expect that European and American culture can be transplanted bodily and *in toto* to the low wet tropics, except in small centers maintained at considerable expense for strategic or political reasons.

Yet we must grant that the world as we know it is operating more or less in consonance with deep-lying fundamental principles which are part and parcel of this European-American culture or Western civilization. Whether we like it or not, we must recognize the existence of capitalist economics (whether privately or state controlled), nationalistic politics, monogamic marriage and small family units, machine technology, dependence upon artificial sources of power, literacy and rapid communication, and all that these words imply. And it is perfectly apparent that the indigenous cultural systems of the Amazon-Orinoco-Guiana region are in most respects inherently unfitted to "get along" with a Western civilization containing these complexes and drives. While the complexion of Western civilization may change with altering political or military fortunes, it seems unlikely that the basic complexes mentioned above will disappear completely from the world system for many decades or even centuries, barring a total collapse and "return to barbarism." Therefore the problems of this area seem to boil down to the following terms. European and American culture, adapted to middle latitude environments, can not be transplanted or borrowed *in toto* in the low tropics of South America. On the other hand, the indigenous cultures, although providing a material adaptation to the environment, are incapable, without radical reorientation and modification, of gearing into a world system dominated by Western civilization. It is the task of anthropology to investigate the actualities and the potentialities of an emergent civilization in this region, adapted to the environment, but capable of standing on its own feet in the world arena. The instability of the native situation under the old imperialist exploitation during the depression was apparent to many observers, of whom Earl P. Hanson was perhaps the most articulate in a number of articles and in his book "Journey to Manáos."

The task of the anthropologist with respect to these problems might be phrased in terms of the following questions. Is there any evidence that a culture, combining certain elements of aboriginal cultural adjustment (*e.g.*, house types, food, clothing, etc.) with values and techniques derived from Western civilization, may be arising? Japan, for example, represents a society which has adopted certain Western traits of culture (*e.g.*, capitalist economics, machine technology, military tactics and weapons, etc.) without loss of many indigenous cultural elements. This blending process has given Japan a position of independence and reciprocal function in the world. Is a similar process developing, or capable of developing, in the Amazon-Orinoco-Guiana region? We do not mean to suggest that an exact parallel with Japan will be found, but this case is mentioned in order to indicate that what may happen in one society may, in a general way, occur elsewhere, namely, in South America.

As with race mixture, so also with cultural mixture we are not dealing purely with hypothetical possibilities. A considerable number of trained observers have described various aspects of acculturation within the region. Nordenskiöld dealt in a number of publications with early post-Colombian European contacts with natives and traced the diffusion of certain European culture

elements, using primarily the linguistic approach. F. Keiter published a survey of acculturation in the Upper Amazon basin based on G. Tessmann's material. Baldus and Petrullo have provided some information on the region of the Upper Xingu and Matto Grosso, Snethlage on Eastern Bolivia, and other authors have dealt in summary or passing fashion with other portions of the area. The present writer's personal observations from Eastern Ecuador and Peru to the Guianas confirm the impressions of other observers that the native cultures are disappearing, not into a European culture as we generally understand it, but into a synthesis composed of European and native elements. The time has now come to proceed from these somewhat random studies and impressions to a systematic consideration and investigation of the whole problem.

Perhaps the emergent cultures of the Amazon-Orinoco-Guiana region could best be studied through the regional approach, using some of the concepts and techniques developed by American geographers and sociologists, together with ethnological methods of acculturation study already proven successful by anthropologists. In the Amazon Valley one region of this type is that comprising Eastern Peru and Ecuador, with its cultural center at Iquitos. The regions of Manáos, Pará and Santarém, the Upper Orinoco, Orinoco delta, etc., might be similarly studied. And with the anthropologist we might expect other social scientists, particularly the geographer and economist, to cooperate in investigations of a more specialized nature.

Once in possession of the data concerning racial and cultural change and blending in this region, scientists as well as "practical men" concerned with human problems would be in a better position to shape the future course of relations with South America, and policy-makers in South America itself would have a firmer basis on which to proceed. With respect to population problems, we might call attention to the present overcrowding of the colored population in parts of the West Indies, for example, Puerto Rico and Jamaica. It is conceivable that scientific studies of the lowland tropics of South America would indicate this to be a land of opportunity for colored migrants.

In emphasizing the opportunities for research in the lowland tropic region we should also point out that similar anthropological studies are applicable to other portions of South America. Particularly in the Andean republics it seems that nativistic elements, their blending and cultural adaptation, will present important problems for the future. The rise of Aprismo and of self-conscious native literary movements in these areas are only two indications that old conditions are changing.

In short, the argument of this paper is that human resources are of equal importance with "natural" resources in our relations with foreign areas, and that the sciences of man should not be left out of consideration in such relations. To illustrate this point we have directed attention to South America and to the least developed portion of the continent, the tropical lowland area.

BOOKS ON SCIENCE FOR LAYMEN

ARE WE COMING OR GOING?[1, 2]

READING one of Professor Hooton's recent books is like panning for gold—with the exception that Hooton does the "panning," and it is the reader who must search for a few grains of gold or, mayhap, even a nugget or two. The two books above listed are quite similar in content and in theme. The 1939 volume is a collection of sundry Harvard Alumni Club luncheon talks; the 1940 volume an extension of the five Vanuxem Lectures at Princeton. There is in each an outline of human evolution, a discussion of human races, and a general viewing-with-alarm and pointing-with-scorn. The 1940 volume adds a discussion of infra-human Primate behavior and human body types.

Any thinking person who scans the world scene to-day and who reads the record of twentieth century history, will agree with Professor Hooton that something's wrong, that man has made a mess of his social structure.

It is in the diagnosis of basic causes that the author strikes out vigorously. He is convinced that man's "biological inferiority"—the culmination of an evolutionary process accelerated and accentuated by civilization—is at the root of all criminal behavior and all social inadequacies. In the conflict between biological determinism *vs.* social opportunism Hooton backs the former, regards the latter as an "also ran." In charging that medicine and social science have neglected human biology and human heredity in favor of environmental conditioning he goes to the other extreme and virtually neglects environment. This may be no more than the shock psychology of over-exaggeration, to stimulate the physician and the social scientist to meet the bio-anthropologist at least half-way. The pendulum, swinging free, goes to extremes, but it soon gravitates to a balance. At the moment Hooton has the pendulum in biological imbalance, as it were.

Man is biological, but he also is a social being. His biological make-up must inevitably condition his social pattern; but likewise is it true—whether equally true or not, we'll not say—that the totality of his environment must shape the expression of his biological constitution.

The statement that criminal behavior is associated with a given physical type ("mosaic" of morphological traits) pays too little attention to the social aspect of the definition of what constitutes a crime. During Prohibition it was a crime to possess liquor; now it is not. Yet many of us, no different physically now than then, were "criminals" every time we partook of some liquor "just off the boat!" Man defines the crime, not crime the man, and criminal opportunity bulks at least as large as the criminal's physique. We are products of time, yes, but time may be measured in the social set-up of the moment.

Professor Hooton outlines an aggressive program for the study of man's constitution. In forceful and often witty style he points out man's shortcomings and suggests a program—largely eugenical—for setting things right. His is the biological approach. It must be complemented by a program of social integration. A concerted biologico-social study of man is now indicated—not merely a questionnaire type of social program in august dignity or a statistical and morphological investigation in aloof solitude. Teamwork is the answer!

W. M. KROGMAN

[1] *Twilight of Man.* E. A. Hooton. Illustrated. x + 308 pp. $3.00. 1939. Putnam.

[2] *Why Men Behave Like Apes and Vice Versa.* E. A. Hooton. 1940. Princeton University Press.

UP FROM THE ALGAE[1]

For forty-five years Campbell's "Mosses and Ferns" has been the standard text for the morphology of these groups. Now in his eightieth year the author carries to completion his great project of dealing with the morphology of all vascular plants.

The obvious popular appeal of the title is not quite borne out by the contents and could not be because no one can yet map the evolution of the higher plants, for "It is not expected that all the conclusions presented by the writer will meet with general approval but it is hoped that they may direct attention to much-needed investigation of many disputed points in the classification of embryophytes which is at present in need of thorough revision." Read in the spirit of this sentiment the book is an extremely valuable contribution. It really consists of a compendium of present-day information on the structure and development of plants from mosses to flowering plants, together with as much of the theoretical evolutionary path over which they have traveled, as may be made out at the present time.

The first section of the book on the Bryophytes looks familiar to a student of the earlier "Mosses and Ferns." But in the later sections the progress of science, especially in the discovery and interpretation of fossils gives the book an aspect which could never have been anticipated by the student of 1895.

The first of these discoveries came with the gradual realization by a number of different workers, in the next decade, that the "fern leaves" so abundant in the coal measures were seed plants (Pteridosperms) not related to the ferns at all.

A second major change was introduced by the discovery of Kidston and Lang in 1921 in the Devonian rocks of Scotland of curious vascular plants which partook of the character of Thallophytes, Bryophytes and Pteridophytes, but could not at first be assigned to any of these. They were slight upright plants with conducting tissues as in the higher plants but without differentiation into any of their organs, *i.e.*, leaf, root or stem. These plants, Rhynia and Hornea, are now considered a primitive type of Pteridophyte, but in reaching this conclusion ideas of phylogeny of the higher plants had to be pretty thoroughly revised.

The third revolutionary discovery during the half century covered by Campbell's studies was Wieland's elucidation of the detailed structure of fossil cycads in 1906. This work demonstrated the distinctness of fossil cycads (Bennettitales) from their living relatives and furnished the data from which Parkin and Arber elaborated what is by many regarded as the best theory for the origin of angiosperms. On this theory the conelike flowers of magnolias are regarded as primitive. Later Bessey and others built systems of classification (and they believed of the phylogeny) of the flowering plants, starting from Magnolias and Buttercups.

Campbell rejects these newer ideas of the origin of flowering plants, deciding (rightly) that the evidence supporting them is inconclusive, and takes up the system of Wettstein, which regards the amentiferous oaks and walnuts as primitive and derives most of the other flowering plants from ancestors of this general type. With this, as Campbell recognizes, many will disagree. For while it appears to accord better than Bessey's system with the earliest angiosperms we know as fossils, it fails to connect with any particular gymnosperm type which can be regarded as ancestral.

The adherents of the opposing theory maintain that the earliest angiosperm

[1] *The Evolution of Land Plants.* D. H. Campbell. Illustrated. 731 pp. $6.50. 1940. Stanford University Press.

floras known to us represent a great advance beyond what the first (unknown) angiosperms must have been. Thus one of the earliest of certainly identifiable angiosperms (early Cretaceous) is the Sycamore, Platanus; and concerning this Seward[2] remarks: "This forest tree exhibits no features which stamp it as a primitive type or as one of the earliest members of an evolutionary series." In the upper Cretaceous, moreover, there were about 70 families of angiosperms, covering almost all types, from the lowest to the highest.

Thus the origin of the angiosperm remains the chief problem of plant phylogeny. Campbell by summarizing existing knowledge has in effect clearly stated the problem and so should facilitate its solution. The book is one which will be used constantly everywhere plant morphology is studied.

ROBERT F. GRIGGS

FACT GATHERING[1]

HISTORICALLY the oldest and, from a purely factual standpoint, the most basic, phase of biological science—the description and classification of the forms of life, the classical field of taxonomy, has been accused, and with reason, of contributing but little to the ever-changing facies of the main currents of biological thought. The essential value of its work in the gathering of facts for the record to be consulted by workers in other fields has never been questioned, but until very recently systematics was looked upon as without much general interest or even application to other branches of biology. However, with the vast advance in purely systematic knowledge and particularly with the great increase in detailed data on certain groups, it has now become possible for the specialist in other lines to check his theories and more accurately formulate his questions, to find material for new paths of experimental departure and to build up new chains of inductive reasoning from the once neglected, and even scorned, field of taxonomy. Not only do the data of systematics thereby cast a correcting and directing influence upon the philosophical background of current work in genetics, cytology, embryology, ecology and other specialties, but also the impact on these data of minds trained along other than taxonomic lines has tended to mold purely systematic work as well. It is therefore at a most propitious time for biologists that a book dealing with the "new" systematics makes its appearance.

This book is issued under the sponsorship of the Association for the Study of Systematics in relation to General Biology under the editorship of Julian Huxley. Besides a valuable introduction by the editor, it contains twenty-one chapters, each with a different authorship, and, fortunately, each with a useful literature list. All that can be done in the limited space at the disposal of the reviewer is to list some of the chapter titles, in the hope that they may stimulate the reader of this review to go over the book itself. Mutations and Geographical Variation is discussed by Timofeeff-Ressovsky; Taxonomic Species and Genetic Systema by Darlington; Bearings of the "Drosophila" Work on Systematics comes from the pen of H. J. Muller; Hogben writes of Problems of the Origin of Species; de Beer on Embryology and Taxonomy; Calman presents A Museum Zoologists' View of Taxonomy; and Ford gives an account of Polymorphism and Taxonomy.

All the chapters are full of interest and appear to result from much careful deliberation and reflection. The text, on the whole, is free from typographical error, but occasional mistakes have

[2] A. C. Seward, *Plant Life through the Ages*, p. 298.

[1] *The New Systematics*. Edited by Julian Huxley. Illustrated. viii + 583 pp. $6.00. July, 1940. Oxford University Press.

eluded the proofreader, such as, on page 7, where Darwin's book is referred to as "Animals of the Variation and Plants under Domestication" instead of "The Variation of Animals and Plants under Domestication." Two good indices, one of names, and one of subjects, make readily available the contents of a book well worth the attention of biologists of all specialties.

H. FRIEDMANN

IS LIFE A MIRACLE?[1]

THE task of surveying the information we possess concerning animal and plant life is one to be approached with considerable deliberation. The selection of what to give and what to leave out is obviously one of the most difficult to make. Even when the authors have pleased themselves with the reasonableness of the approach and the material submitted, there still remains the very strong probability that few others will agree with them.

This volume is a compilation of chapters by six authors. It begins with the dawn of life, proceeds through the various phases of evolution and then turns its attention to the animal kingdom. There is no attempt to become involved in the intricacies of classification. The speed with which the invertebrates are dispatched is amazing. The emphasis rather falls around the discussion of various topics such as animal courtship, how animals make a home, modes of travel and the like. The plant kingdom finds itself in between the earlier animal evolution and animal kingdom sections and the large later section on various phases of the biology of man. This concession to any plant miracle again is built around topics like plant anatomy, plants in relation to man and plant breeding. The book then proceeds to devote nearly half of its pages to the story of the human family tree, the races of mankind, human physiology, human psychology and a brief review of some great men in medical history.

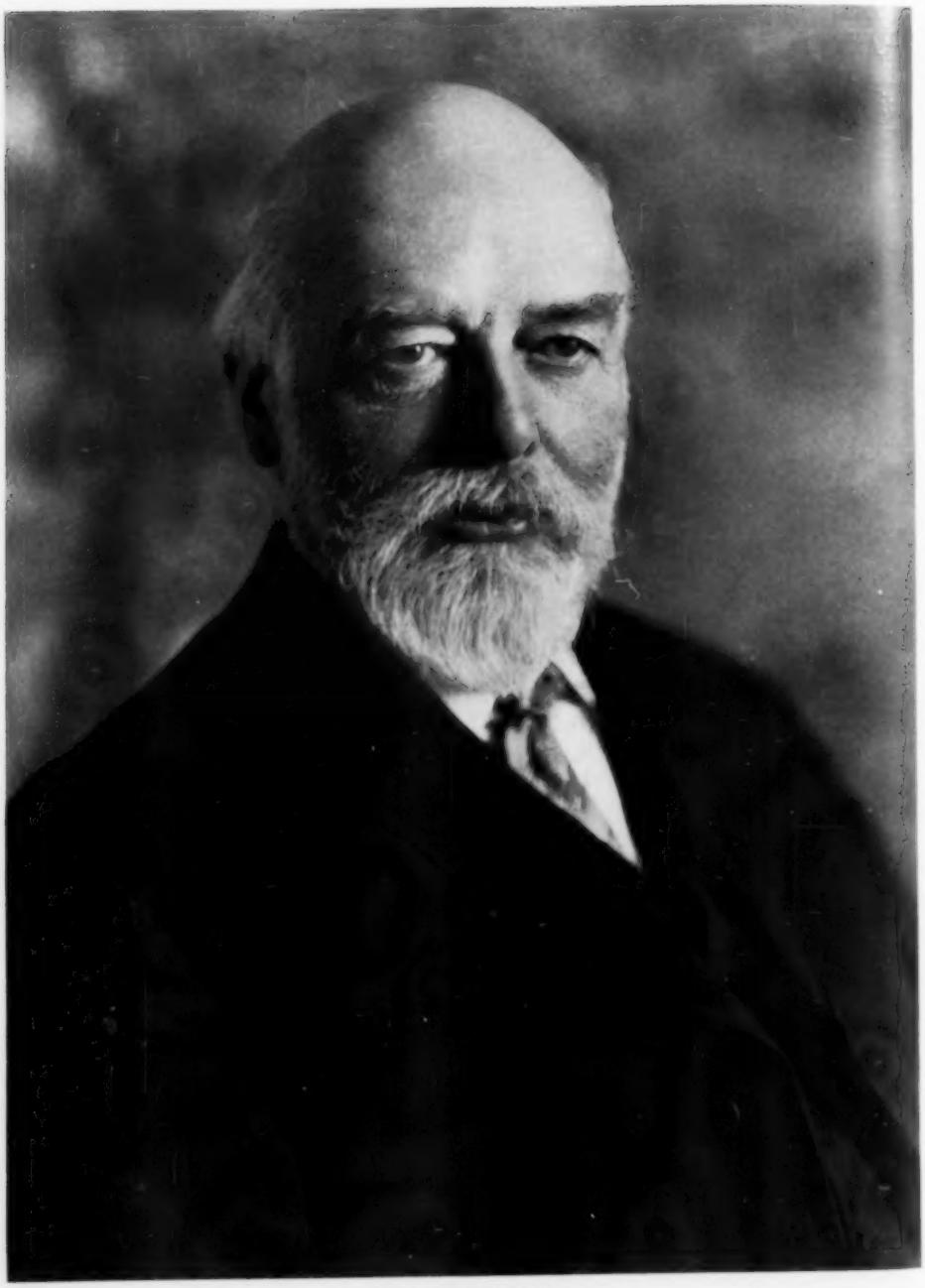
This book is written for the general reader. "The Miracle of Life" has been condensed into 480 pages, with over 500 illustrations taking approximately one third of the page space. The pictures are adequate but poorly printed. The text is sketchy and brief. It further is a distinctly British volume which relies pretty much upon a background of the British Isles. The wrapper informs us that it tells "what modern science knows about all living things: Birth, Growth, Heredity, Instinct, Reproduction, Etc." With that emphasis upon birth and reproduction it is a revelation, if not a minor miracle, to find the phenomena in man are covered in three pages without any pictures whatsoever of the reproductive apparatus. This volume surely will not offend the most conservative home of even thirty years ago.

To the person with a biological background this volume is elementary to the extreme, and will receive merely an examination of its pictures. Our readers of *Science* will be delighted to learn that the deer bot fly still travels over eight hundred miles an hour. No one will dispute the miraculous nature of this myth.

In spite of its weaknesses, it is a volume that is full of information in readable form. The pictures are its chief source of attraction, and may insure that some of the text will be perused. For one who knows little about biology, here is a good place to begin. It is in no sense a technical book, and will find a place in a personal library of a general nature. It surely will acquaint the general public with a mass of biological knowledge.

IRA B. HANSEN

[1] *The Miracle of Life*. Edited by H. Wheeler. 480 pp. Halcyon House.



OLIVER LODGE

THE PROGRESS OF SCIENCE

SIR OLIVER LODGE, 1851–1940

To the "man in the street," the typical professor of natural philosophy is a man of dignified bearing with strongly developed features, a man having the appearance occasionally of being lost in the clouds while peering into the mysteries of the universe, a man, nevertheless, of great action and energy, a man fearless in the cause of his convictions, a man able on occasion to stir the multitude with the profundities of his learning, yet one humble in himself, and the faithful servant of his Creator. Few typify this conventional ideal as did Sir Oliver Lodge. To the layman, he was probably better known than any other living man of science, a fact for which his strong personality was largely responsible, enhanced as it was by a clarity and simplicity in writing and speaking which enabled his hearers to understand the message, and to become incited to enthusiasm for it.

A product of the school of classical physics and of the era in which the science of electrodynamics was born, Lodge was a firm believer in the reality of things; and while open to conviction in respect of the new, he sought always to cement it to the fabric of the old. The aether in his eyes was a very real medium. Its equations to him were the servants of its substance, and he had little sympathy with the kind of substance which had no parentage other than in the equations. He was one of those pioneer experimenters who, seeking to make the aether declare itself in all its actions where moving bodies are concerned, evolved a series of results which, unassailable in accuracy, were yet inconsistent with each other in the spirit of thought of the day and which, in the hands of the more venturesome Einstein, led through the intermediary work of Larmor and Lorentz to the concept of the theory of relativity.

Enthused with the revelations of the work of Faraday and Maxwell, Lodge's first important investigations had to do with lightning rods and the general subject of electrical oscillations. As a by-product of this work, he was responsible for the invention of a method of dispersing fog. He almost anticipated the work of Hertz on electrical oscillations. He invented the "coherer" and was the first to transmit wireless messages over considerable distances. It is probable that had his knowledge of the science of electricity and magnetism been less he would have been encouraged to pursue these investigations into that realm of practical wireless telegraphy whose successful realization fell to the fortune of others in later years. The fact is that in terms of the knowledge of those times, a realization of transmission of electrical signals over a distance comparable with the earth's radius seemed a fantastic impossibility. Indeed, it is ony the more recent discoveries of the existence of special conditions in the upper atmosphere, and associated with the Kennerly-Heavisidean Layer, that have enabled experiment to be crowned by theory with "common sense."

Oliver Joseph Lodge was born on June 12, 1851, at Penkhull, near Stoke-on-Trent, England, and received his early education at Newport Grammar School. He received much of his early advanced education in physics at University College, London, and obtained the degree of doctor of science in 1887. Following a lectureship on physics at Bedford College for Women, he was appointed assistant professor at University College, and in 1881 he was elected first professor of physics at Liverpool. In 1900 he was

appointed principal of the new university at Birmingham, which position he held until 1919. In 1877 he married Mary, the daughter of Alexander Marshall, and his family comprised six sons and six daughters.

Lodge is the author of several books, such as "Elementary Mechanics," "Modern Views of Electricity," "Pioneers of Science," "The Ether of Space," which have been a source of inspiration to countless physicists and doubtless have inspired many of them to specialize in the field of electrodynamics. In addition, he is noted for his writings upon matters pertaining to psychical research, to which subject he gave considerable attention during the latter portion of his life. In this realm, while he was probably the most outspoken of his contemporaries, he was not alone, for Sir William Crookes, Lord Rayleigh and indeed Sir J. J. Thomson, also, viewed these matters as worthy of consideration.

Sir Oliver Lodge was always a striking figure in any assembly of men of science; but in spite of his dominating personality, he was a man of kindly sympathy and was greatly helpful in his encouragement of others. He was, indeed, an ornament to science and a lovable link between the physics of to-day and that of the era which is past.

W. F. G. SWANN

INVESTIGATIONS AMONG THE CARRIER INDIANS OF BRITISH COLUMBIA

THE Carrier Indians in the vicinity of Stuart Lake, British Columbia, were visited during the summer of 1940 in order to study certain problems of the relationship of primitive economics to social and political organization. The Carrier are exceptionally suitable for a study of this kind because several marked changes in the framework of their socio-political organization during

CARRIER FISHERMEN STILL USE DUGOUT CANOES
ON STUART LAKE, WHICH ARE OFTEN POWERED BY OUTBOARD MOTORS.

MODERN CARRIER FOOD CACHES ARE BUILT OF LOGS

the prehistoric period can be reconstructed and because the impact of European culture on their own during the historic period has been more orderly and less devastating than among most Indian tribes.

The Carrier inhabit a vast territory between the Rocky Mountains and the coastal ranges of British Columbia. In subsistence terms, they occupy a region where the hunting and fur trapping area of the great Canadian interior and the salmon area of the Northwest Coast overlap. Game and fur-bearing animals killed in the extensive forests and fish caught in the headwaters of the Fraser and Skeena Rivers have always contributed about equally to Carrier existence. To-day, most Carrier Indians have exclusive rights to trap-lines which are registered with the government of British Columbia. These registered trap-lines permitted a somewhat novel and fruitful field technique. Starting with maps of present-day holdings, the succession of land ownership was traced back through five generations and concomitant changes in social and political usages recorded. Earlier changes were reconstructed by comparative ethnography. Three main stages of Carrier development were reconstructed.

At one time the Carrier, like the other Athabaskan tribes of the interior of Canada, lacked clans and a hereditary aristocracy of wealth. Land was probably held and exploited communally by bands in which all people were substantially equal. But in comparatively recent prehistoric times matrilineal clans and a potlatch system spread up the Skeena River from the Tsimshian Indians and were introduced first to the Babine Lake Carrier, later to the Stuart Lake Carrier. Tracts of land came to be held by "nobles," who gave potlatch feasts to support their titles and who inherited both land and titles matrilineally, within clans, from their mothers' brothers. The mechanics by which this new type of land tenure and use were substituted for the old system can not be known in detail. Two features of the older Carrier culture, however,

DEMONSTRATION OF NATIVE METHOD OF WEAVING FISH NETS

DOGS ARE TRAINED TO CARRY LOADS OF AS MUCH AS FORTY POUNDS

probably facilitated its adoption: Cross-cousin marriage and bride service. If it had been customary that a man marry his mother's brother's daughter and go to live at her house for several years before and after his marriage, the introduction of the new system meant merely that he would inherit his father-in-law's, that is, his mother's brother's titles and property and that his children would belong to his wife's clan.

By the time the white man arrived in Carrier country, achievement of status by wealth had become a dominant theme in Carrier culture. A somewhat greater wealth made possible by the white man's superior technology—steel traps, guns, axes, and so forth—at first intensified the old system. Potlatches involved bigger feasts and a greater quantity and variety of goods to distribute to rival nobles. But eventually, other influences from the white man began to undermine the native institutions. The Catholic Church banned cousin marriage and discouraged potlatching. A desire to keep rather than to distribute wealth and increasing importance of individual ownership and of patrilineal inheritance of land caused more and more nobles to divide their estates among their own sons in defiance of the ancient obligation to give it and the potlatch title it supported to their nephews. Registrations of traplines was the final factor that entrenched the new system. To-day, therefore, although the Carrier continue to live mainly by trapping and fishing, their socio-economic unit is the individual family.

Thus, the Stuart Lake Carrier changed from a band organization to a clan-potlatch system and later to a family system without any important modification in the pattern of their economic activities.

A CARRIER WOMAN
DEMONSTRATING THE USE OF ABORIGINAL CARRYING NET AND TUMPLINE.

These changes, therefore, were caused by the external influence of ideologies, a purely historical phenomenon, and not by any kind of "economic determinism."

JULIAN H. STEWARD

EXPEDITION TO STUDY MEXICAN BIRDS

GEORGE MIKSCH SUTTON, Cornell University's curator of birds, and Olin Sewall Pettingill, Jr., zoology professor at Carleton College, led an expedition to the hill country of southwestern Tamaulipas in February to study birds during the breeding season from February to June. With Sutton will be big sheets of paper and a complete water-color outfit for a series of bird paintings. With Pettingill will be cameras and color film. The expedition will center on a pictorial conquest of the birds of the Sabinas Valley and of the mountains west of the village of Gomez Farias.

Headquarters probably will be the Rancho Rinconada, a spot known to Sutton, who worked the Sabinas Valley

briefly in the spring of 1938. The expedition plans to be in Mexico for several weeks so that the ornithologists may obtain data on the wintering bird-life, the transient forms and the courtship, nesting activities and territorialism of the breeding species.

"The region is particularly rich in tropical birds," said Professor Sutton, in commenting on his work in 1938. "Near the Rancho Rinconada we encountered five species of Parrots—the Military Macaw, Red-crowned and Yellow-headed Parrots, Green Parakeet, and Aztec Parakeet; a tinamou; the great-crested Curassow that is known as the *Faisano Real* or 'Royal Pheasant'; the wild Muscovy Duck, and numerous brightly colored small birds, including tanagers, warblers, hummingbirds and buntings. Several kinds of hawks breed in the vicinity, including the little known Crane-legged Hawk, *Geranospiza nigra;* the handsome Mexican Goshawk; the Black Hawk; a middle-sized hawk that is the counterpart of our United States Broad-wing; the trim Bat Falcon; and a long-tailed, bird-eating species known as the Collared Micrastur. Vultures and Caracaras are common, of course, these being the garbage-disposal system of the countryside."

The worst difficulties the ornithologists will encounter will be dysentery and ticks. The ticks, which are variously known as *nighuas, pinelillos, conchudas, grapatas* and *viredores* (whatever the etymology of these words may be!) are very bad in spring. In 1938 Sutton's party had a time with them, finding such items as sulfur, gasoline, kerosene, carbide and alcohol of no use in combatting them. "The *pinelillos* were worst," said Sutton. "They were very small, got onto us by the hundred, and had to be scraped off with knives. But we never had any serious trouble as a result of them." As for snakes, they apparently are rare about the Rancho. The only snakes Sutton and his party saw in 1938 were dead ones along the highway or partly eaten ones that were being carried about by hawks; and none was a rattlesnake.

Sutton's first collection of Mexican bird paintings (a series of sixty heads made direct from life or from freshly killed specimens) was displayed at the International Ornithological Congress at Rouen and Paris, France, in 1938, one of them (that of a Coppery-tailed Trogon) being reproduced in full color in the Proceedings of the Congress and in the French ornithological magazine *L'Oiseau*. Most of them have since been displayed at meetings of the Wilson Ornithological Club, and at a one-man show at the American Museum of Natural History in New York City. Reports on Sutton's 1938 and 1939 bird-work in Mexico have been appearing in *The Auk*, *The Condor*, the *Wilson Bulletin* and the *Annals* of the Carnegie Museum of Pittsburgh. He has prepared a semi-popular book on his 1938 work, but this is not yet ready for publication.

Sutton and Pettingill are old teammates, both of them having participated in the memorable hunt for the Harris's

NOTE: The two bird heads reproduced on this page were sketched by George M. Sutton. The first one is Audubon's Caracara, a common Mexican bird sometimes called the "Mexican Eagle," sketched from a freshly killed specimen by George M. Sutton; the second is the Curassow, known as the "Faisano Real" or "Royal Pheasant," painted from a male specimen. The knob at the base of the bill is bright yellow.

A BAT FALCON

THIS SPECIES NESTS ON THE RANCH RINCONADA, NEAR THE EXPEDITION'S HEADQUARTERS.

COPPERY-TAILED TROGON

ONE OF MEXICO'S HANDSOMEST BIRDS, KNOWN AS THE "QUA" OR THE "FLAG BIRD."

MAKING ORNITHOLOGICAL OBSERVATIONS IN A MEXICAN SWAMP

TICK BITES
ON THE LEGS OF A MEMBER OF THE EXPEDITION AT THE RANCHO RINCONADA.

Sparrow's nest at Churchill, Manitoba, in 1931. They were graduate students at Cornell together in the early '30's, and are, respectively, first vice-president and secretary of the Wilson Ornithological Club. Sutton, who is a fellow of the American Ornithologists' Union, is author of the books "Eskimo Year" and "Birds in the Wilderness" and illustrator of many bird-books, including W. E. Clyde Todd's recently published "Birds of Western Pennsylvania." Pettingill, one of the outstanding bird photographers of the country, has contributed to such magazines as *Natural History*, *National Geographic* and *Bird-Lore*.

Other members of the expedition will probably be Dwain W. Warner, one of Dr. Sutton's graduate students at Cornell, and Robert B. Lea, one of Pettingill's students at Carleton. M. S. P.

AN AUTOMATIC DRIVE FOR THE SCHMIDT TELESCOPE ON PALOMAR MOUNTAIN

FIG. 1. VIBRATOR UNIT
OF TIME STANDARD. DIAMETER OF BASE, 14 INCHES.

DURING the intensive search for supernovae which was conducted with the Schmidt telescope on Palomar Mountain, much time was wasted in manually guiding the telescope. It therefore became desirable to install an automatic drive which would enable us to eliminate manual guiding for exposure times up to thirty minutes.

The new drive, now in use, consists of a synchronous motor supplied with power from a precise, adjustable frequency time standard. The frequency of the standard is varied from sidereal rate by a calibrated amount to compensate for the effect of atmospheric refraction and the fact that in practice the polar axis of the telescope is pointed to the apparent pole rather than to the true pole.

The time standard,[1] shown in the ac-

[1] A complete description of this time standard is given by the inventor, Henry E. Warren, in *A.I.E.E. Transactions*, March, 1940.

companying photograph, consists of a vertical wire tensioned by a weight, and is kept in transverse vibration at its fundamental frequency. A small bar magnet attached to the midpoint of the wire is coupled with pick-up and feedback coils, these coils being connected to a simple vacuum tube circuit which maintains the wire in vibration.

By proper choice of the dimensions and materials of the upper and lower halves of the wire, the frequency of vibration is made substantially independent of the temperature. Also by use of a bow spring coupling between the wire and the tensioning weight, the frequency is made substantially independent of variations in the amplitude of the vibration. The unit in use at this telescope has the tensioning weight adjusted to produce a frequency of vibration of 60 cycles per sidereal second. The precision of the time standard is about one tenth of a second per day.

The lower portion of the tensioning weight consists of a cylindrical Alnico magnet, in the air gap of which is a coil of fine wire. Flow through the coil of measured direct current of proper sign and magnitude causes a downward or upward force on the weight, causing in turn a definite increase or decrease in frequency. The current to this frequency adjusting coil is set to the proper value by means of a rheostat, as indicated by a milliammeter calibrated directly in "seconds of arc per hour" deviation from sidereal rate. The rate deviation is read from a chart, giving its values for various declinations and hour angles.

Although a drive of the type described should, in all directions in the sky for which the differential refraction does not become too great, allow us, without manual guiding, to obtain images which do not exceed the limiting size of photographic point images (about 30 μ), prac-

FIG. 2. STAR PHOTOGRAPH WITH NEW SCHMIDT TELESCOPE

DURING THE 30-MINUTE EXPOSURE THE TELESCOPE FOLLOWED THE STARS IN THEIR DIURNAL MOTIONS AND CORRECTED FOR THEIR APPARENT DISPLACEMENTS PRODUCED BY REFRACTION OF THE ATMOSPHERE, ENTIRELY BY AUTOMATIC CONTROL DESCRIBED IN THE TEXT.

FIG. 3. STAR AND METEOR SPECTRA
ANOTHER DIRECT PHOTOGRAPH OF A REGION OF THE SKY WITH THE TELESCOPE GUIDED AS BEFORE, IN WHICH THE STAR-IMAGES ARE SPREAD OUT INTO SPECTRA BY A FULL-SIZED PRISM MOUNTED IN FRONT OF THE TELESCOPE. THE LONG, BRIGHT DIAGONAL TRACE IS DUE TO A BRIGHT METEOR THAT FLASHED ACROSS THE FIELD DURING THE 40-MINUTE EXPOSURE.

tical errors are introduced because of the mechanical imperfections of the gear train which couples the telescope tube with the driving motor. The deviations of the drive were determined by observations of the excursions of a star from the cross hair in the guide telescope attached to the main tube. A 24-hour plot (in five-minute intervals) revealed the existence of a periodic error of 8 seconds of arc $\times \sin(2\pi t/T + \alpha)$, where, if the time, t, is measured in minutes, we have $T = 24$ minutes, plus some additional small and irregular errors. A potentiometer driven from the telescope gearing gives a sinusoidally varying voltage of proper magnitude, period and phase, such that, when this voltage is impressed across the rate-adjusting coil of the time standard, the periodic error is essentially removed by alternately driving slower and faster than the normal rate.

For routine exposures of 30-minute duration, the procedure has been to set the telescope at the desired position for taking the photograph, set the rate dial at the proper value, start the film exposure, leave the telescope for the exposure period and return only to close the shutter and to change plates. It is now possible for one person to take photographs practically continually and yet have all the plates developed, marked and partially examined by the end of the night. This speeding up of the work with Schmidt telescopes should prove particularly effective for programs such as the search for supernovae and common novae, whose early discovery is of importance.

In Figs. 2 and 3 are reproduced enlarged sections of films which were obtained with the 18-inch Schmidt telescope driven entirely automatically. The direct photograph in Fig. 2 shows that the diameters of the images of the faintest stars are only slightly larger than 30 μ which is approximately the diameter of the limiting photographic image. Fig. 3 is the enlarged reproduction of an objective prism photograph obtained during a 40-minute exposure which was guided entirely automatically. Both the slight increase in the size of the images in Fig. 2 and the slight widening of the spectra in Fig. 3 are due to the small irregular differences between the motion of the telescope tube and the motion of the stars, differences which still remain after the average rate of driving is set correctly and the fundamental periodic error of the worm gear is automatically compensated for.

For the classification of spectral types of stars unwidened spectra as those shown in Fig. 3 are not suitable because of the difficulty of identifying enough spectral lines. The spectra may con-

veniently be widened with the automatic drive by setting its rate slightly off from the correct rate.

For some purposes, such as the determination of the magnitudes and colour indices of faint stars, very perfect images are needed for the production of which our automatic drive is not quite accurate enough. Also, the work with some of the filters requires exposure times much longer than 30 minutes during which the differential refraction both in declination and right ascension may become appreciable. In this special case it is necessary to consult from time to time the guide telescope and to reset the position of the main tube in declination and hour angles as well as to change the rate of the drive.

E. J. POITRAS and F. ZWICKY

INDIVIDUAL VERSUS GROUP MEDICAL CARE

NATIONAL interest is being centered upon the trial in Washington, D. C., of the American Medical Association on charges of violating the Sherman Anti-Trust Act by "boycotting" the Group Health Association, a local medical cooperative. The trial, which opened on February 5, is not expected to end before the middle of March, and, regardless of the verdict, it will probably exert considerable influence upon the practice of medicine in the United States.

The immediate occasion for the trial was the attitude of the American Medical Association and three other medical organizations towards the establishment of the Group Health Association in Washington. Typical of a number of medical cooperatives springing up throughout the country, this group sought to carry out a plan whereby the services of physicians and the facilities of clinics should be pooled and made available to subscribers on the basis of monthly payments. The Group Health Association, originally organized on an unofficial basis among employees of the federal government, received a $40,000 loan from the government Home Owners' Corporation and now has a membership of about 3,000.

The Trust Division of the U. S. Department of Justice, which is acting as prosecutor in this case, accused four medical societies and twenty individuals of monopolistic practices in coercing hospitals and individual physicians into refusing to treat G. H. A. patients. The four medical societies named in the indictment were the American Medical Association, the Medical Society of the District of Columbia, the Washington Academy of Surgery and the Harris County Medical Society of Texas. Fifteen of the individuals indicted are physicians practicing in Washington, while the others consist mainly of officials of the American Medical Association, including Dr. Morris Fishbein, editor of the Association's *Journal*, and Dr. Olin West, secretary and general manager of the Association.

The alleged "boycott" had gone on for two years when indictments were returned against the physicians and the medical organizations. These indictments were at first held invalid by the District Court on the ground that the practice of medicine was not a "trade" within the meaning of the Sherman Anti-Trust Act, but this ruling was reversed in March, 1940, by the Federal Court of Appeals, which upheld the indictment. The United States Supreme Court refused to reverse the ruling again, and remanded the case to the District Court for trial.

The views of the contending parties were elaborated in the preliminary statements made at the opening of the trial by attorneys for both sides. John H. Lewin, special assistant to the attorney-general, accused the defendants of obstructing the organization of the Health

Group and of handicapping its work. The District Medical Society, for example, was alleged to have sought to "crush and destroy" the G. H. A. by preventing any of its members from joining the new clinic's staff, by obstructing attempts to staff the clinic with non-members of the society, by personal attacks on the men who did join the staff, and by inducing all the local hospitals to join in the boycott by refusing courtesy privileges to G. H. A. practitioners. He announced that the first witnesses on his side would consist of well-known liberal surgeons who have been prominent in the group health movement and who would stress the social advantages of the plan.

William E. Leahy, counsel for the defense, criticized the management of the Group Health Association. He accused its founders of being motivated by commercial motives, and said that it was dedicated to the disruption of the traditions of the medical profession. He accused the cooperative of seeking to wipe out opposition to its medico-economic theories by undermining the American Medical Association and the District Medical Society. He accused medical cooperatives of being economically unsound and unable to provide patients with the care they promised. He denied the allegations that the medical societies had sought to hamper the cooperative's activities. Refusals of hospitals to allow G. H. A. practitioners to operate in their buildings were stated to have been motivated solely by a desire to keep their standards high. B.I.G.

NEW AUDITORIUM AT THE COLORADO MUSEUM

In the closing years of the last century, in a picturesque log cabin in the heart of the Rocky Mountains, a small collection of mounted birds and animals was assembled by lovers of the fauna of the West. From these humble beginnings the collection rapidly grew until it attracted state-wide attention, and in 1900 it was incorporated as the Colorado Museum of Natural History. A large museum building was constructed in 1908, with funds supplied by the state and by the city of Denver, to house the expanding collections of the museum. Every ten years since that date has seen the construction of new additions to the museum's plant. In 1918 the Standley Memorial Wing was constructed, in 1928 the James Memorial Wing was built, and the Phipps Auditorium—the newest addition—was begun in 1938.

The Phipps Auditorium, a new wing to the main building of the Colorado Museum of Natural History, was opened recently in Denver. The dedication ceremonies took place on January 11 and included speeches by the governor of Colorado, the mayor of Denver, the director of the museum and other dignitaries.

The wing is named in honor of former United States Senator Lawrence Phipps, of Denver, who presented $137,500 to the museum to construct the auditorium. In presenting the gift, Senator Phipps stated that he "had long appreciated the desirability of a suitable auditorium which would fulfil cultural needs by making a common meeting place for those interested in arts and sciences." A grant of $112,500 by the Public Works Administration supplemented Senator Phipps's gift.

The building, designed by Roland L. Linder, is 98 feet long and 140 feet wide, and seats one thousand people. Space is provided for a concert organ and the stage can accommodate a seventy-five piece orchestra. The latest type of standard and 16 millimeter motion picture projection equipment has been installed, so that educational programs for adults and children may be presented. Motion picture programs have been ar-

THE PHIPPS AUDITORIUM OF THE COLORADO MUSEUM OF NATURAL HISTORY
WHICH WAS OPENED RECENTLY AND HAS A SEATING CAPACITY OF 1000 PERSONS.

ranged each Saturday morning for children, and a Sunday afternoon series for adults will include lectures by naturalists, travelers and explorers.

Simultaneously with the construction of the Phipps Auditorium, work has been going forward on new cases for habitat groups in the Standley and James wings of the main building. These cases, illuminated with fluorescent lights, will have concave backgrounds with domed ceilings, and will have plate glass fronts 7½ feet high and 13 feet long. The habitat groups will represent fauna and flora from localities throughout the Americas, and will include scenes from Bering Sea Islands, the Arctic ice floes, the Alaskan tundra, the Bonaventure Islands off Newfoundland, and varied localities in Brazil. A number of specimens in these groups will be taken from the museum's bird groups, which will be dismantled. A group of W.P.A. artists, under the supervision of Curator Robert J. Niedrach, are now painting panoramic views for each group. B. I. G.

THE CENSUS

It is said that statistics are dull. They are to those who do not realize what they mean. But often they tell an absorbingly interesting story, as do those contained in the United States Census. Whenever we attempt to obtain a picture of the amazing changes that have taken place in this country, we are grateful that the first article of the Constitution provides that a census shall be taken once in each ten-year interval. The census records that have accumulated since the first census in 1790 now consist of more than 8,000,000 pages.

In 1790 about 95 per cent. of the population was rural; now only 23 per cent. live on farms. But in general to compare 1790 with 1940 is almost like com-

paring another planet with the earth. Even since 1900 the changes have been astounding. Forty years ago on the average about 17.6 persons out of a thousand died each year; now only two thirds as many. On the other hand, in 1900 about 30 children were born, on the average, per thousand of population; now fewer than 17. In the eight years from 1921 to 1928, inclusive, 2,200,000 more children were born than in the eight years beginning in 1929. The decrease in the young and the increase in the aged are presenting many new problems.

Habits, even food habits, of the people of the United States have changed greatly. For example, in 1889 the average per capita consumption of wheat per year was 223.9 pounds; in 1932 it was 162.2 pounds. The per capita annual human consumption of corn in the same interval decreased from 117 pounds to 21 pounds. On the other hand there were great increases in the consumption of citrus fruits, for example. In 1920 there were twenty million orange trees; in 1935, thirty-nine million. In 1920 there were three million grapefruit trees; in 1935, thirteen million. Food faddists will claim that these changes in diet explain the great decline in the death rate, but an analysis will refute the claims, for the greatest reductions in death have been in those of infancy and those due to infectious diseases. And those opposed to the eating of meat will be dismayed by the fact that its per capita consumption has decreased only a little.

Perhaps some of these figures may be thought to have a bearing on the fact that in 1920 the average value of farm land was $69 per acre and in 1935 only $31. There are, however, many other factors, including other habits of our people and international markets for farm products. A factor of major importance is the very great reduction in both the hours of manual labor and in the percentage of the population engaged in manual labor, the percentage of unskilled laborers having decreased by 25 per cent. between 1910 and 1930.

F. R. M.